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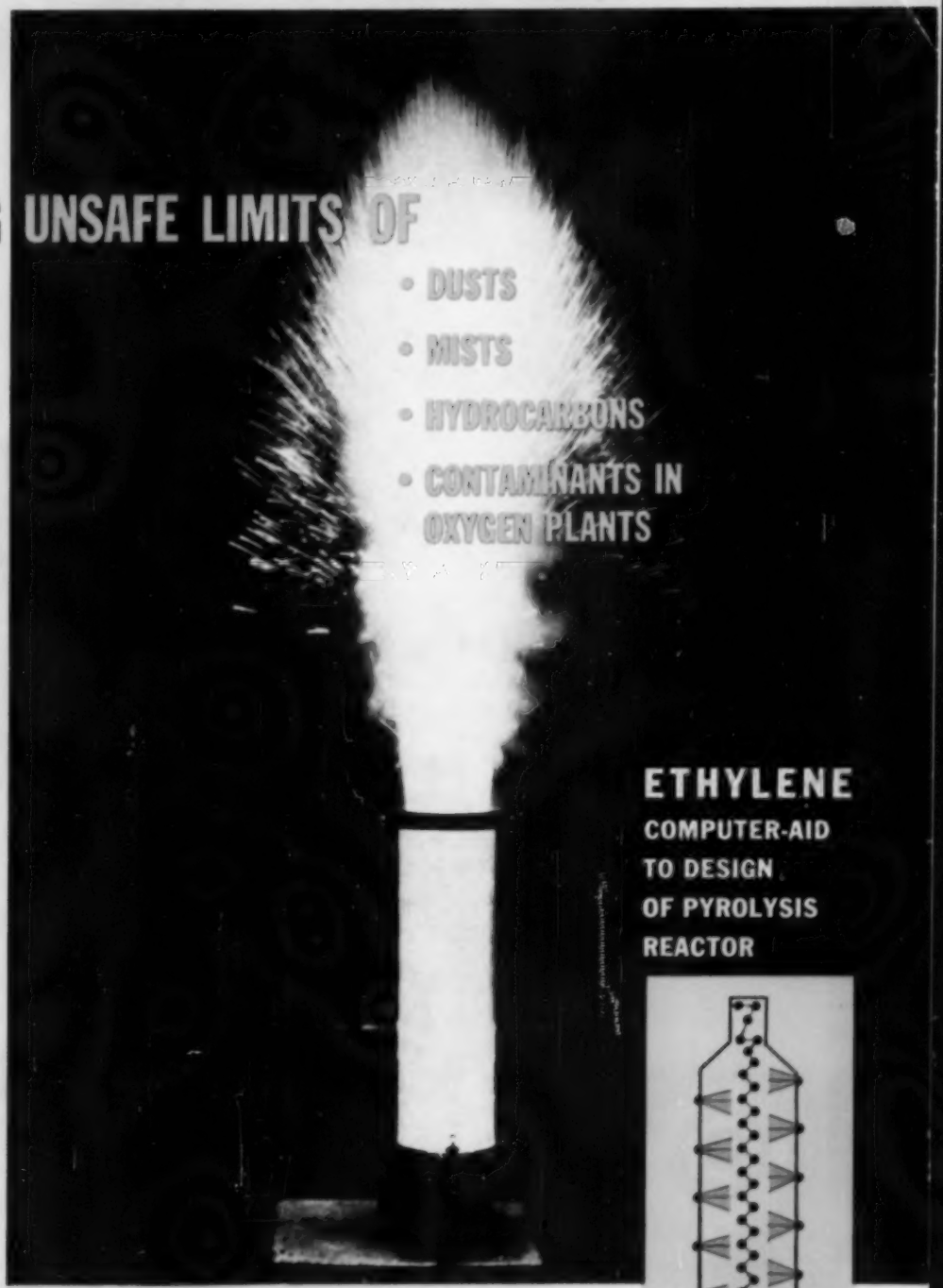

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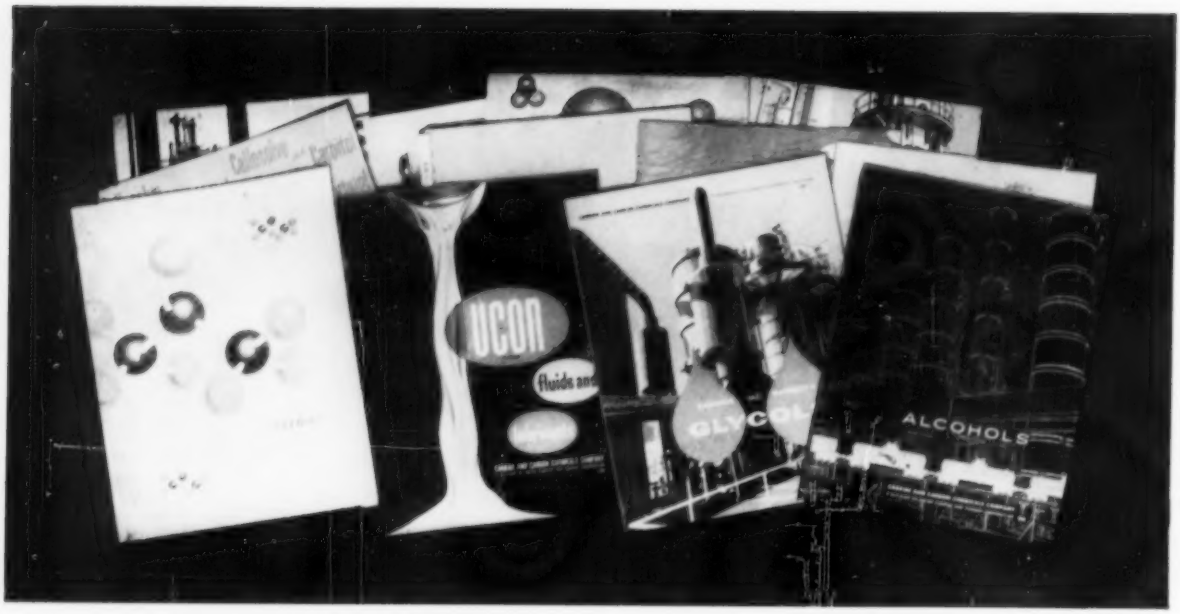

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Chemical Engineering Progress

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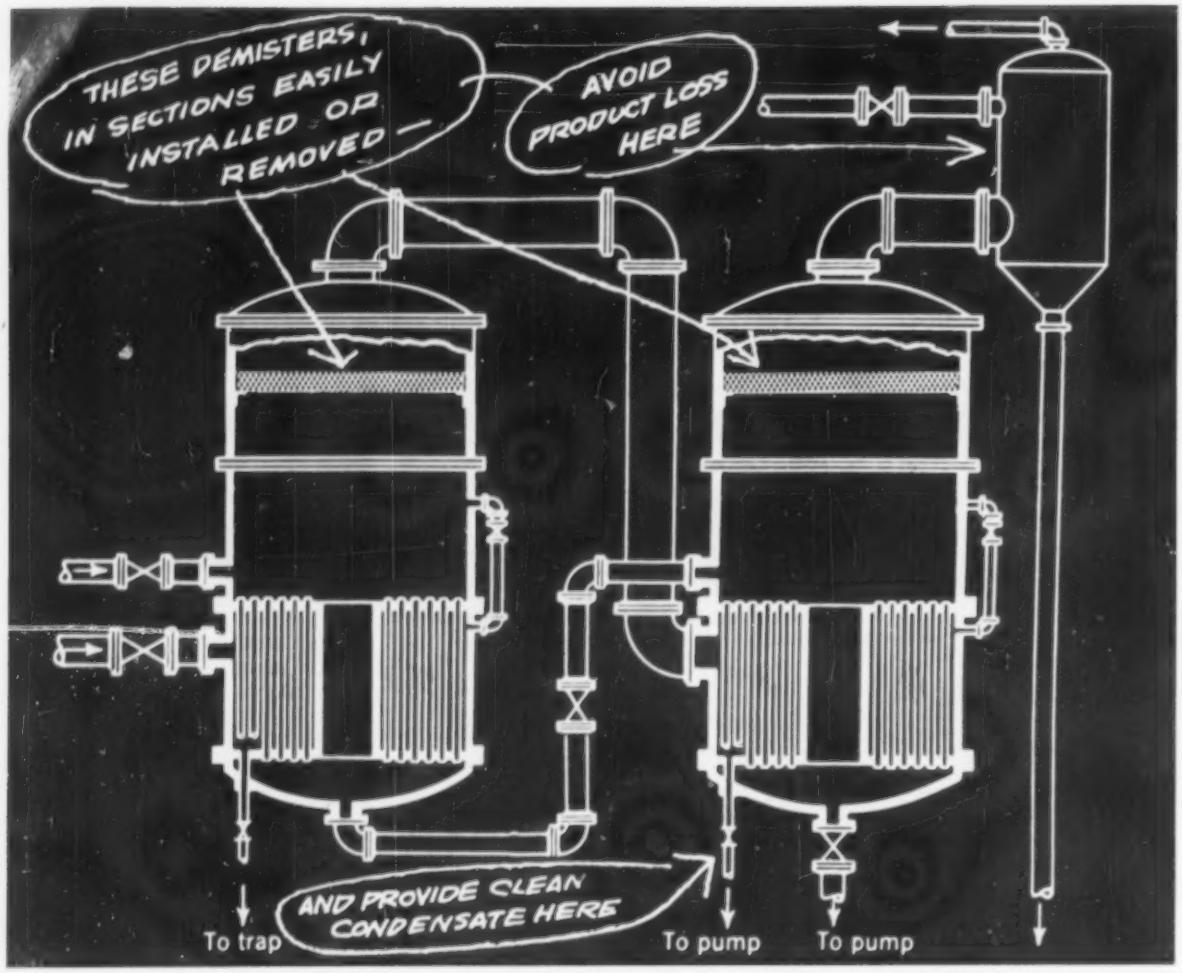

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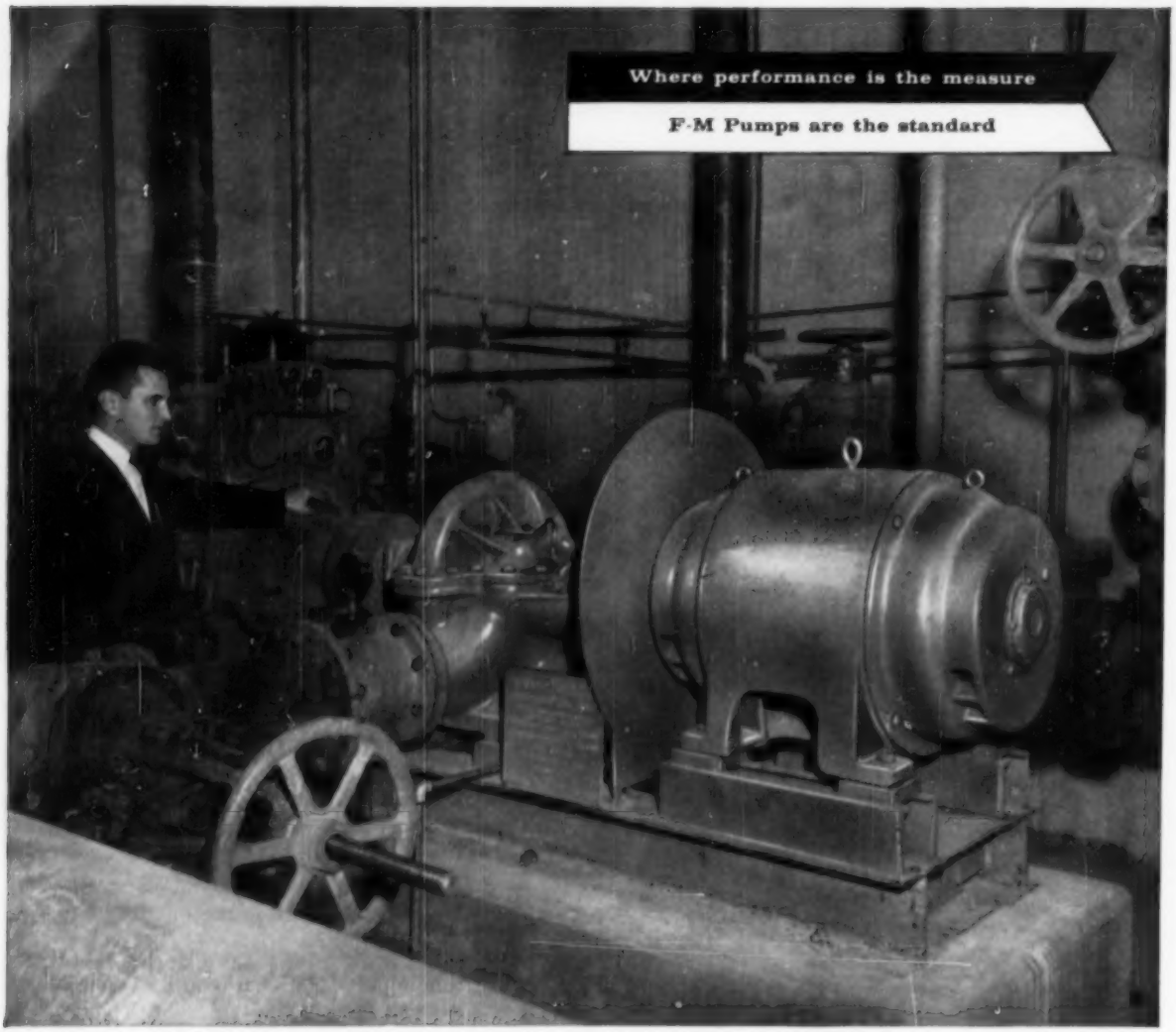

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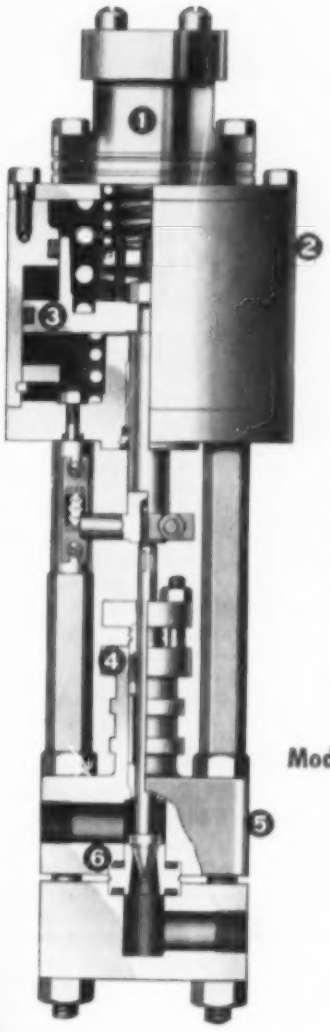

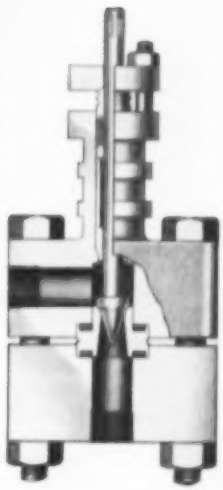

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TWO VIEWS ON WHY THE ENGINEERING PROFESSION IS NOT GETTING THE RECOGNITION IT WANTS

Noted and quoted

An educator attributes the engineer's professional status problems in part to a rising anti-intellectualism, outlining some of its current manifestations. A chemical engineer blames the nature of engineering work itself—being one step removed from direct contact with human problems, the engineer finds it difficult to get public acceptance on an equal footing with the physician and lawyer.

The Engineer and the Climate of Opinion

. . . The modern climate of opinion [has been said to have] four distinguishing features: . . . first . . . it is in a constant state of change . . . second . . . since the world is in motion, we must, in order to explain anything, understand where it came from and where it is going . . . third . . . we deal with "brute, irreducible facts" rather than abstractions or philosophic ideas, and finally, we are [today] concerned with measurement, with quantity and size.

. . . The engineer is the product of this climate of opinion, and in turn helps to form it. Obviously he must assume responsibility for his part. In order to do this he must understand this climate and be aware of its flaws and weaknesses.

Why do science and [engineering] play so large a role in our society? Why have we become known as a technological civilization?

We need not rehearse all the inventions of the nineteenth and twentieth centuries to emphasize the scientific and technological qualities of our climate of opinion. The advances of these sciences have been little short of phenomenal. But as a consequence our society is a materialistic one . . .

Now, at the time when the scientist and engineer seem to be in control of our climate of opinion, there are signs of revolt apparent in the rise of anti-intellectualism, which takes various forms. The engineer's world is founded upon reason, upon the intellect. Without the abstract sciences, without mathematics and physics, engineering would wither and die . . . Ever mindful of this need, it behooves him then to oppose anti-intellectualism, which threatens the life of science, and to encourage the growth of abstract knowledge, research in the pure sciences, the pursuit of truth.

Anti-intellectualism scorns science because the latter does not cure all of society's ills, because the world does not seem to be a better place—in short, because science has not proved to be the panacea it was hoped it would be.

What are these anti-intellectual movements that seem to be modifying the climate of opinion, threatening the scientific viewpoint?

One is [in connection with] a revival of orthodox, evangelical religion . . . The [reaction of many is to seek] a new mysticism, a belief in supernaturalism, an attempt to return to primitive magic. Sects and churches that offer the security of a well-ordered heaven and hell are flourishing.

(*Continued on page* 15)

Is Professional Recognition the Individual's Problem?

We hear a lot of talk these days about the dissatisfaction of engineers and scientists with their professional status, or lack thereof. According to the findings of the National Industrial Conference Board [*CEP*, 22, Jan. '50] . . . many engineers and scientists are turning toward unions because they are not satisfied with the way their employers are treating them. On the other hand, [one hears] engineers complain that they are not treated with the same respect given to doctors and lawyers. . . .

Why do engineers want this recognition, and why don't they get it? In the first place, it seems . . . pretty elementary that all three of the "learned professions" are made up largely of people who deal directly with the public in their own names . . . One thinks of a doctor or lawyer as an individual who has acquired considerable personal knowledge and ability which he can put to work for you when you need him. He is dealing directly with the public and by law must be licensed to protect the public from malpractice and lack of professional ethics.

Engineers and scientists, however, are generally employed by companies, although consulting engineers do operate more in the manner of the lawyer. Thus, when you need engineering work, you are usually employing a firm, which in turn employs engineers, and the integrity of the firm is your protection. More often you are buying a product which has engineering work behind it rather than actually using the engineers' talents directly. . . . Engineers and scientists don't work with human ailments, problems, and vagaries, as do the "learned professions," but more with the laws of nature and matter, which are not well-comprehended by the general public. After all, aren't the feelings, actions, and progress of *people* of most significance in our civilization? The *things* that the engineers design, manufacture, or operate are only means to the end. Since engineers and scientists are thus one step removed from ministering directly to people, it seems quite normal to us that their recognition by the public is not on the same plane with the recognition accorded those who deal with personal problems. . . .

In [my] mind, professional recognition for engineers will always be pretty much a mutual admiration proposition. You can't expect a housewife to admire the man that produced a more efficient engine half as much as she admires the surgeon that sewed up her six year old son's head after he fell out of the tree, or the lawyer that got her husband cleared of a murder charge. It just isn't human nature, and we are going to have to face it. We can, however, take pride in jobs well done, in creating things for the good of mankind, and in teaching others who would follow our professions. A great deal of satisfaction may also be obtained by being active in technical societies, publishing or presenting technical papers, or becoming a recognized authority in a given field. Thus we can gain considerable recognition within our own ranks.

If, on the other hand, we want the public at large to recognize us individually, each of us is going to have to do something directly for the public to earn it, perhaps serve in public office, or be active in community affairs. This is a matter for each of us to handle as individuals first and engineers or scientists second. In [my] opinion, we cannot expect either a union or a professional society to do it for us.

Norman C. Updegraff,
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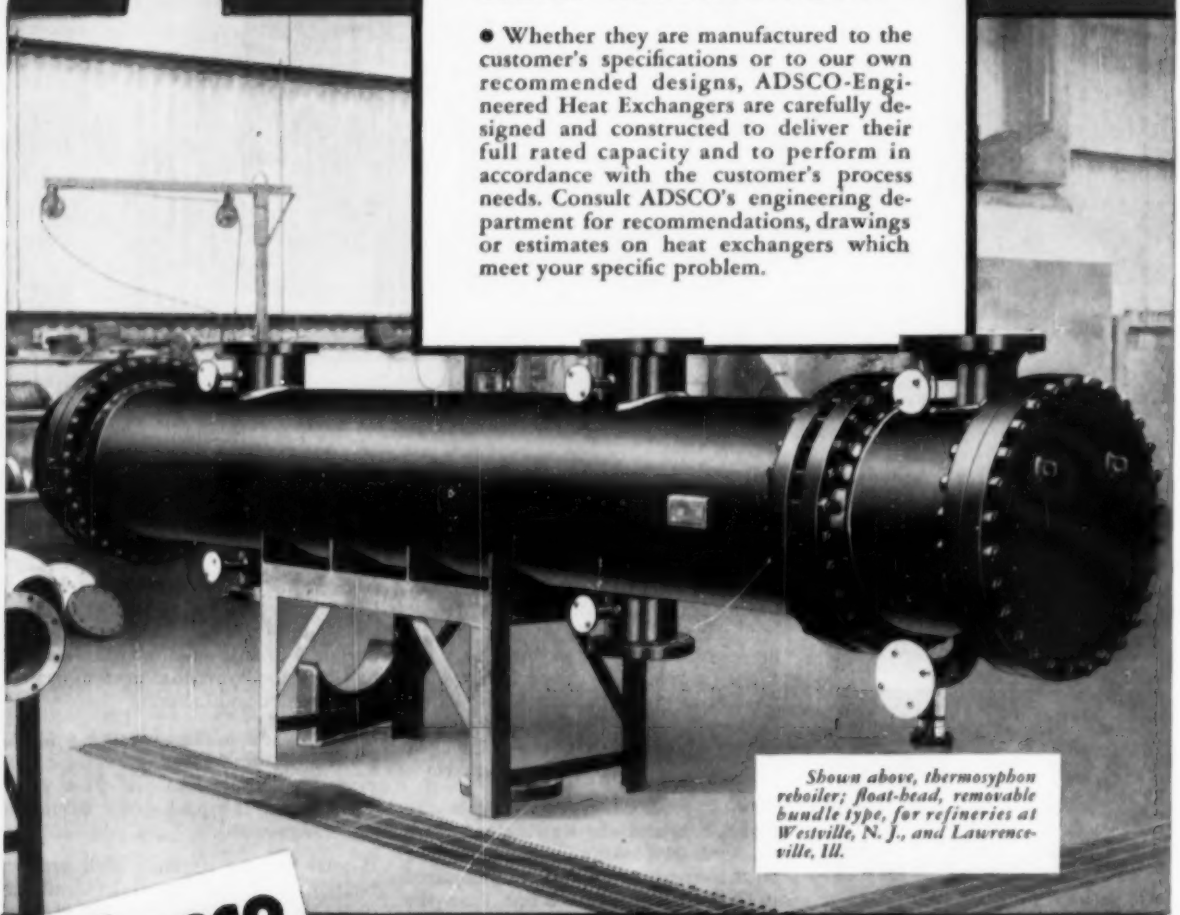

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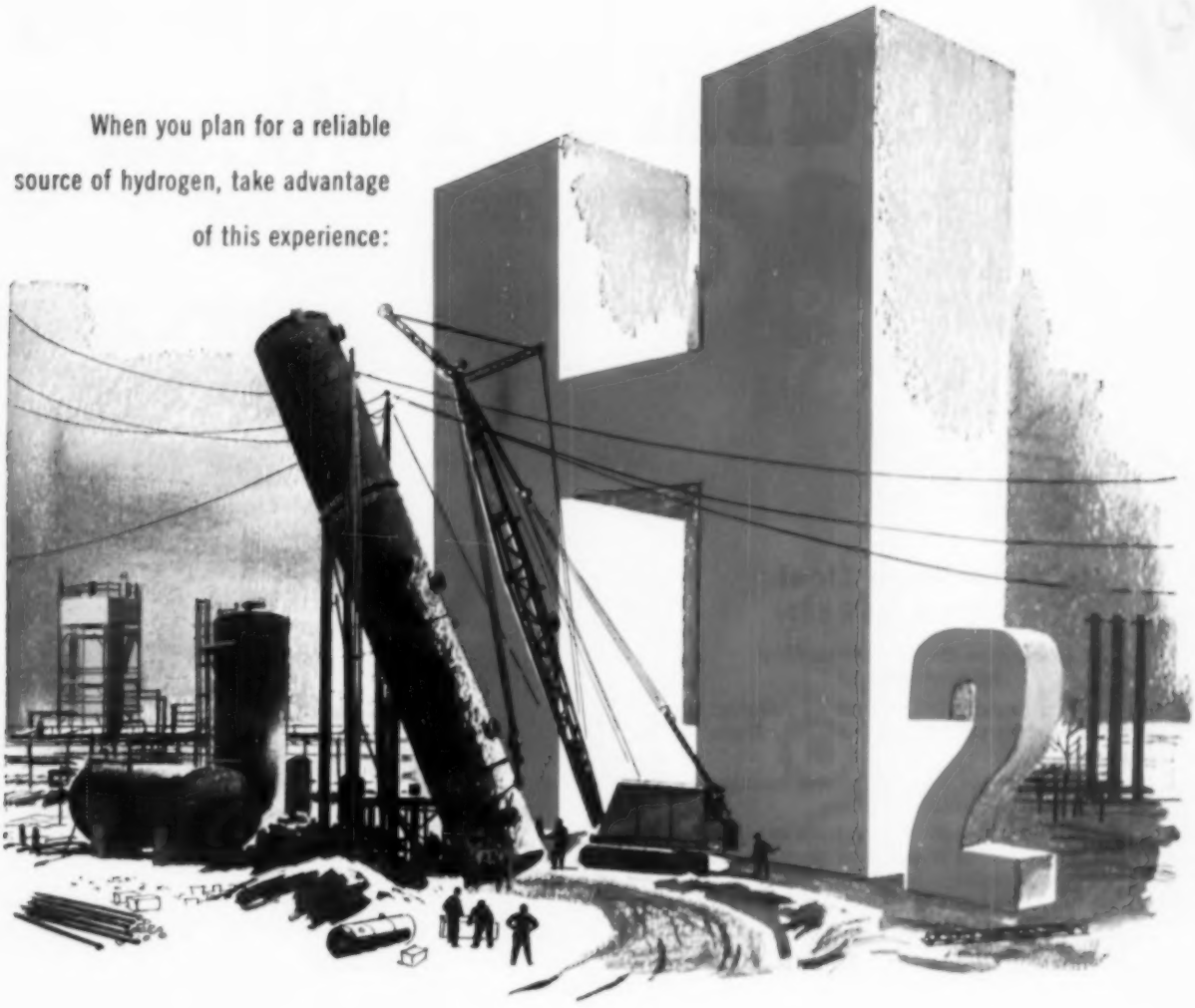

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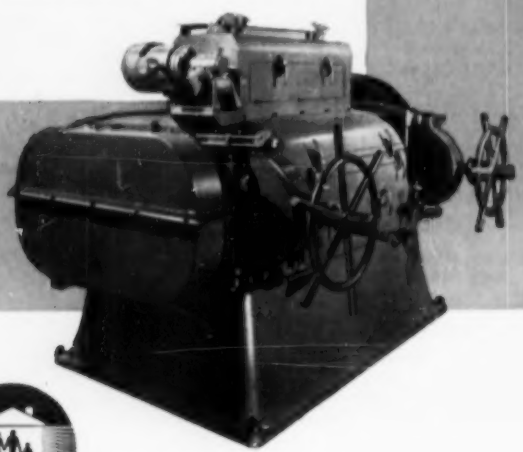

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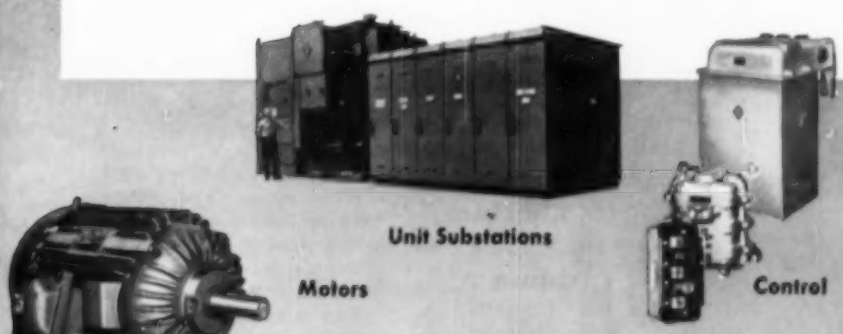

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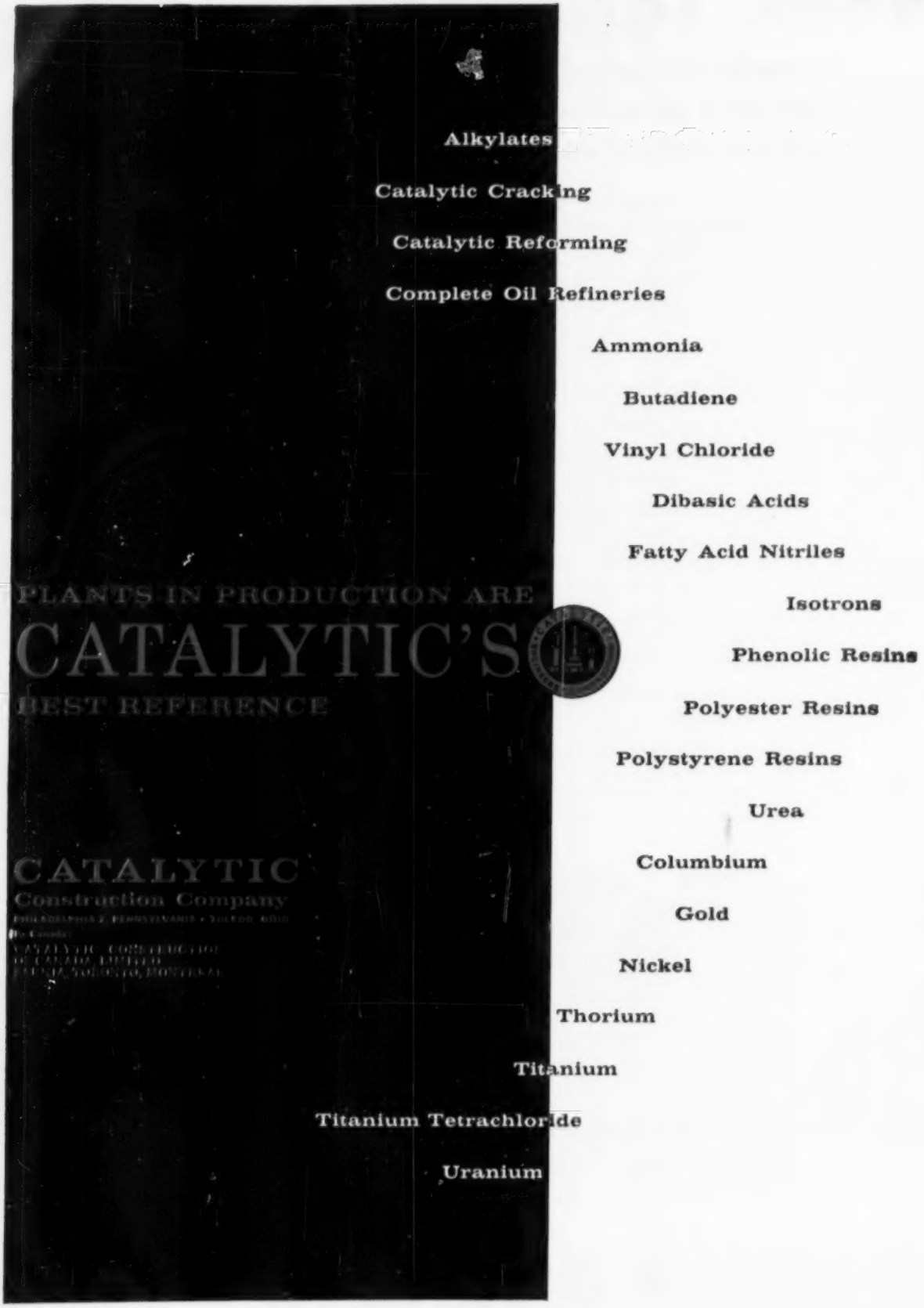
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(*Continued from page* 8)

Another manifestation of anti-intellectualism is the worship of the label "average American." Standardization tends to stifle innovations, individualism, non-conformity. Only the majority is right; minority rights and interests are disregarded. We must beware lest our self-complacency crystallize our whole culture and prohibit growth, expansion, or change. Standardization also fosters an irresponsibility, a lack of integrity, in the individual. It becomes easy to shuffle off the task of making decisions and judgments, and to escape one's moral responsibility by following blindly the laws and regulations of institutions or government and the patterns and mores of society.

Erich Fromm has put it this way: Man has transformed himself into a commodity, experiences his life as capital to be invested profitably; if he succeeds in this, he is "successful," and his life has meaning; if not, "he is a failure." His "value" lies in his salability, not in his human qualities of love or reason or in his artistic capacities. Hence his sense of his own value depends on extraneous factors, his success, the judgment of others. Hence he is dependent on these others, and his security lies in conformity, in never being more than two feet away from the herd (1).

Another aspect of anti-intellectualism has risen from a school of psychology that tells us that man is not responsible for his actions, has no free-will and does not "think" or reason. He is the sum total of the variables of his environment. If man is conditioned altogether by his society, and society is wholly responsible for him, conformity—even rigidity—of the social pattern is a necessity, and automation is complete.

Anti-intellectualism bombards science from yet another position. Unfortunately some people assume that knowledge [itself] is evil; therefore they resent and fear intellectuals. . . .

Finally there are the pseudo-scientists and charlatans, who, with a little learning and no ethical principles or intellectual honesty, bring dishonor upon all intellectual pursuits. These unscrupulous individuals are more readily discovered in medicine and other scientific areas, but they are insidious in any realm of study. Neither quackery nor dilettantism can be tolerated by the sincere pursuer of truth.

These, then, are the forces of anti-intellectualism that seem to be growing in our time. All of us—humanist and scientist alike—have a stake in this battle. We must not regress into a world of black magic; we must persist in pushing inch by inch the cutting

(*Continued on page* 16)

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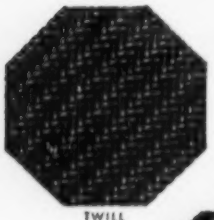
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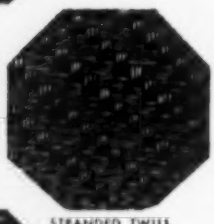
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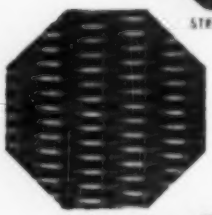
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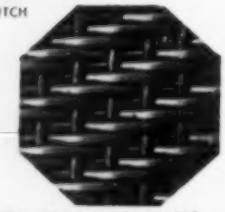
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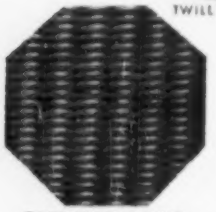
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(Continued from page 15)

edge of knowledge more deeply through the darkness. The scientific method and scientific research are among our finest pieces of equipment. . . . Educators involved in engineering education . . . need to alert the engineer to the dangers of anti-intellectualism, to make him aware of his need for the pure scientist and for the humanist. Then and only then will he have found himself, his place in society, and his significance in the evolution of civilization.

First of all, he must be aware of his dependency upon pure science and abstract thought. The engineer must have the principle, the hypothesis, the theorem, to serve as the base for the erection of his monuments. Very recently Professor Von Karman stated that the Americans had the "know-how," but the Europeans had the "think-how." Obviously, a society needs both. Whitehead declared that a "civilization which cannot burst through its current abstractions is doomed to sterility after a very limited period of progress. An active school of philosophy is quite as important for the locomotion of ideas, as is an active school of railway engineers for the locomotion of fuel." (*2*) . . .

The engineer's need of the humanist is perhaps less tangible than that for the pure scientist, but is nonetheless real. Those of us working in the liberal arts have witnessed again and again the personal growth of an engineering student who responds to the stimuli of his courses in the humanities. . . .

As an educator I would say to an engineering student: know your subject as thoroughly as possible and honor your skill, your "know-how." But beware of anti-intellectualism in its many forms which would destroy the works of science and discredit the scientific method. Recognizing your dependency upon abstract thought, respect and foster the pursuit of knowledge for its own sake; and realizing that you must learn to live with yourself and with your fellow men, cultivate the arts and the humanities. . . .

Sarah Ruth Watson,
Penn College, Cleveland, Ohio

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2. Whitehead, Alfred North, *Science and the Modern World*, 86 (N. Y., 1925).

Adapted from a paper delivered before ASEE 64th Annual Meeting and which appears unabridged in J. Engrg. Educ. Jan. '57.

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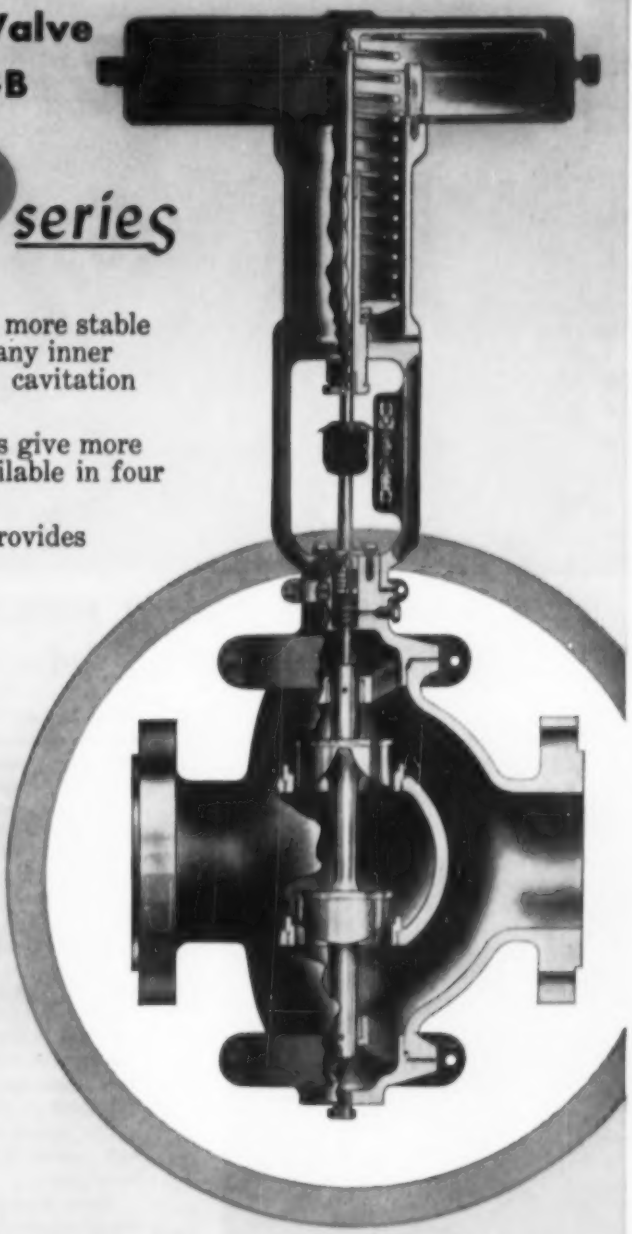

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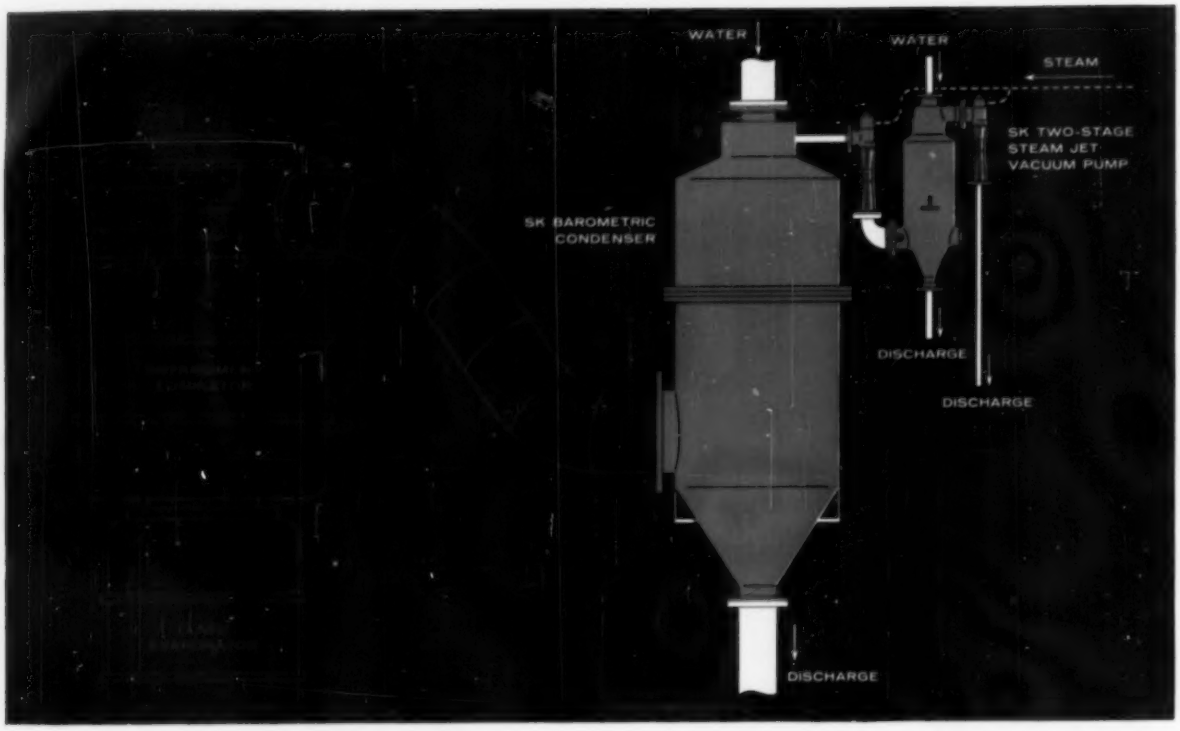

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ENGINEERING TODAY

By Warren K. Lewis

During recent years there has been a great deal of soul-searching and frustration among engineers because of what the engineer feels is inadequate public recognition of the dignity and status of his profession. In this situation is it not highly desirable to look over the family history, to see what lessons for the future can be drawn from the experience of the past? I am convinced that a study of this kind can be constructive for the engineers of the twentieth century.

How it all began

When the Roman Empire was overrun by our barbarian ancestors 1500 years ago, the resulting social chaos swept away almost everything of the culture and of the social and political organization of the past. As a consequence, conditions of life reverted to an extremely primitive state, out of which slowly developed the cultural pattern of the Western World. However, even at the start of that development, the preservation and practice of certain basic skills was so important that something had to be done about it. Recourse was had to the age-old apprenticeship system, under which a boy who wanted to learn an art served as an assistant to a practitioner, working for him and learning from him. This system was adopted in all areas: in medicine, the apprentice served under a physician; in textiles, he served under a weaver. In time, the arrangement developed a specific, systematic form, recognized by law, because it was understood that for each group, organization was necessary to guarantee the maintenance of proper standards of training and performance and to protect the interests of the group from encroachment. The Latin name for such an organization was *universitas*, the equivalent of our modern term, *corporation*.

At the start, all these groups were organized alike, but as time went on, simultaneously with the development of a standardized form of organization, it became clear that certain types of work required a quantity and quality of training that could not be assured by the master-apprentice system. Thus, the physician's apprentice needed to devote an amount of time and energy to reading and study far beyond that needed by the weaver's apprentice. This obviously interfered with the service which the physician's apprentice could render his master in return for the privileges he was receiving. Moreover, the physician under whom the apprentice served might, for example, be a skillful practitioner, but ill qualified to teach and guide the student in the philosophy of his art. Hence, it is not surprising to find that at an early date certain groups began to modify the apprenticeship system by the gradual segregation of the teaching function from that of practice. The groups of craftsmen thus finally developed into the guilds of the middle ages, each made up of masters, journeymen, and apprentices, the master responsible for the training of the apprentice for which training the apprentice paid by the work he did for the master. The other groups finally met their problem by the development of schools rather than depending on practical experience as an adequate source of training. The first of these was the medical school at Salerno, established just about a thousand years ago. These schools, in the process of their development, have preserved the word *university* to modern times as the name for their system of organization and method of training.

The universities of the Middle Ages served to train four groups of students: in the schools of arts (whose most important function was training for general education), law, medicine, and theology. In process of time, these four groups became the learned professions and gave us the terms *profession* and *professional* with all their connotations to the modern world. The function of these professions was to give intellectual leadership and service, each in its own area of human interest and activity.

Guilds and university schools develop

On the other hand, the province of the craft guilds of the Middle Ages was the production of material goods. They also served a highly useful historic function. They preserved their arts and developed them highly. Even more important, they became the nucleus and focus of the economic and social forces that broke up the feudal system and transformed the social and political system of the Western World. However, they finally outlived their usefulness and, under the impact of political and economic forces far beyond their power to control, they disintegrated and disappeared. Nonetheless, out of their ashes rose, phoenix-like, the modern trade union and modern engineering. We are really brothers under the skin. The function of both of us is the production of material goods. No wonder the older professions look down condescendingly upon us engineers when we have the presumption to claim professional status beside them. They consider us as the equivalent of one of the craft guilds of modern industrial civilization.

However, one should never forget that the university schools, like the guilds whose development they paralleled, were vocational. They trained students to earn their living. The important thing that differentiated the universities from the guilds was the fact that the schools imposed and maintained a severe intellectual discipline as a factor essential to insure the competence of their graduates. This the guilds never did.

There is another chapter in our family history which is also important to us. Almost exactly two hundred years ago, a young man named James Watt, who had served a limited time as an instrument maker's apprentice, got the job of mathematical instrument maker at the University of Glasgow. At the university was Joseph Black, professor of chemistry, and it is well to remember that Black was the discoverer of latent heat and sensible heat, and the first to differentiate clearly and unequivocally between heat and temperature. With Black, Watt was on close terms of friendship and cooperation. Watt, given the job of reconditioning an old Newcomen steam engine, set out to improve it—specifically, to reduce its inordinate consumption of steam. Thwarted in his attempts, he did a new thing under the sun. Instead of continuing to fiddle with the engine, he went into the laboratory and started to study and measure experimentally the physical properties of steam. Out of this work came, it is true, the modern reciprocating steam engine. But far more significant, out of it came a new method of achieving human progress—the application of the knowledge and method of science to the solution of the practical problems of industry and life. James Watt was the world's first engi-

neer in the modern sense.* Insofar as engineers follow and develop the method of Watt, we lay the first claim to recognition as a new profession, because the method requires a severe intellectual discipline as a factor essential to insure competence in its practice. In this regard, we have no apologies to offer.

Our second claim to recognition as a professional group rests upon the magnitude and the quality of our achievement. The trouble is that the engineer fails to grasp the extent of his contribution to civilization and, more seriously still, fails to appreciate its significance. All too often he thinks of his contribution as the gadgetry of modern life—automobiles and telephones, airplanes and television, radar and rockets, whereas in fact these are secondary and, indeed, fundamentally unimportant almost to the point of irrelevance. The real contribution of engineering to life is its development of improved methods of producing, at a lower expenditure of human effort, the material goods men must have to live.

ABOUT THE AUTHOR

Salty New Englander Warren K. Lewis is known to many as one of chemical engineering's truly great originals. Joining MIT's staff in 1910, "Doc" (as he is known) has been a major influence in the development of many of the modern concepts of chemical engineering. It was because of his long record both as a technologist and as a humanist of the highest order that he was invited to present the Eighth Annual Institute Lecture at Boston (December 1956) which provided the basis for this article.

Yesteryear and today pictured

Human imagination cannot grasp the improvement in the standard of living brought about by the engineering achievements of the last two hundred years. A century ago, fewer than one child in twenty in this country ever entered high school. This was not because either parents or public failed to appreciate the value of education. The trouble was that the productivity of human labor was so low that the child had to go to work to help support the family. Today, more than eighty per cent of our youngsters go through high school and we are talking about putting fifty per cent of them through college. The reason we can do it is because of the almost incredible increase in the productivity of human labor made possible by the developments in applied science.

Forty-seven years ago, I went to work as a chemical engineer in a small plant in New Hampshire. The work week was seventy-eight hours. The purchasing power of the weekly wage was less than one third of what it is today. The transformation in the standard of living of the working man in a mere half century is difficult to grasp, even for one who has lived through the process. The younger generation, never exposed to the old conditions, is completely incapable of appreciating the difference. Moreover, the transformation is the result of the new and more efficient methods of production of goods introduced by the engineering profession. A recent article ascribed the result to a free economy. This doubtless helped, but without the new methods a free economy could accomplish little. The transformation is an engineering achievement. One must repeat, the important thing is not the new gadgets. The important thing is freeing men from drudgery, release of time, creation of leisure. Moreover, too much emphasis cannot be put on the point that, in our western industrial culture, this is leisure for everybody.

What leisure means

This revolution has created a new type of civilization in the Western World. Leisure is not culture, but leisure is essential for the development of culture. The civilizations of the past were based upon the leisure of the few, a leisure secured by the toil and drudgery of the many. For the first time in human history, western industrialism has created a new order of life in which both leisure and the wherewithal to use it constructively are available essentially to everybody. This civilization is a new thing under the sun. Its creation was completely impossible without the increased efficiency of human effort in the production of material goods, which has resulted from the work of the engineer.

One must emphasize that the value of leisure depends on what men do with it. The uses of leisure are often unwise, but that does not mean that the leisure is not itself good. Moreover, the use to which men put leisure is not the professional responsibility of the engineer, although it is the responsibility of each of us as a citizen to exert influence in the direction of exploiting it wisely.

Whereas one of our shortcomings as engineers is the failure to appreciate to the full the magnitude and the significance of our contribution to civilization, in endeavoring to remedy this shortcoming we must avoid going to the opposite extreme of failure to appreciate the contributions of other social groups and forces. Labor, management, even the politician, make their contributions, and there is a sense in which these contributions are far larger than our own. On the other hand, they made their contributions before the start of the industrial revolution, but the spectacular increases in achievement which have come since then were impossible without the increase in efficiency of human labor brought about by engineering developments. In this sense, modern civilization is the product of engineering leadership.

First, then, because there can be no question of the technical skill essential for engineering work nor of the high intellectual level of our training for it, and second, because of the character of our economic and social contributions and achievements, we engineers feel that no one should question our right to professional status. However, we realize that this claim of ours is not taken seriously by the general public and we are unhappy about it.

A part of the problem is a matter of phrasecology. When we use the terms *engineer*, *profession*, and *professional*, we are sure to have them misunderstood. In the first place, the word *engineer* is applied to so many different kinds of people, from the fellow who tends the apartment house boiler, to the man who drives the locomotive, to the draughtsman over the drawing board, and on up. The word *profession* is likewise subject to misinterpretation, and even more seriously, the word *professional*. To the man on the street, the connotations of *professional* are pointed up by the current discussion of professionalism in athletics, as an individual paid for doing something for public entertainment which other people do for fun; or that the individual is legally licensed to do a given thing. Small wonder that when, in this country, our societies of professional engineers start to claim special status, the ordinary citizen cannot imagine what the rumpus is about. "These fellows work for pay and are licensed by the state to do it. They call it *registered*, but that is clearly the same thing." It will probably be best, if we want to have the general public take seriously what we mean by a profession, to scrupulously avoid the use of either of the words *profession* or *professional*, and perhaps even of the word *engineer* as well.

* It would seem that the one individual who can challenge the claim is Archimedes, but his example made no impression upon his time. Granting that he practiced a new method, he failed to establish it.

Engineers contribute to art of living

However, the important thing is not what the public thinks about us, but what we think, or ought to think, about ourselves. From this point of view, I feel there are two vital matters in which we fail to measure up to full professional stature. The first of these engineering shortcomings is that, while recognizing our social responsibility in the public interest, we interpret that responsibility far too narrowly. Any group aspiring to full professional status must accept responsibility for leadership in every phase of its area of specialization. Thus, the physician is interested not only in the health of the patient, but in every sort of activity related to health, curative and preventive, public and private. Unfortunately, this is not true of engineers. For example, the production of goods has its human as well as its technical side. In technical matters the engineer is perfectly willing to be held accountable, but his attitude as an engineer is that the human phases of production are none of his business. If the engineer hopes to secure acceptance of his professional status, this attitude must change.

Human relations remains the problem

I have emphasized the social contributions that have resulted from engineering work. However, despite the fact that modern engineering has created the highest standard of living the world has ever known, the worker in modern industry is unhappy. Indeed, in a very real sense, the problem of human relations in industry is the outstanding unsolved problem of the modern world. In this country the living embodiment of the problem is my namesake, John L. Lewis. In England there is the labor party and state socialism. Communism itself purports to be nothing but a better method of organization of human relations in industry. If the unrest that underlies all these problems could be solved, what a Utopia we would have!

However, the engineer insists that this unrest is none of his business. It is true that the engineer discovered the products of modern industry, developed the processes by which those products are made, designed the plant and equipment used in making them, assigned the tasks of labor and supervised their performance. In the face of these facts, can he repudiate responsibility for the human unhappiness and dissatisfaction that result? Yes, he can repudiate it, but in so doing he is rejecting the responsibility which is inherent in professional status and is finding shelter behind the claim that his part in the process of development has been that of a mere technician, with all real leadership in other hands. If engineering aspires to be a profession, this is a damning admission.

Unfortunately, there is still further evidence that engineers are mere technicians. Medicine is fully as specialized as engineering, yet the medical profession has its great professional society, to which its organizations of specialists are subsidiary. We engineers, on the other hand, have our societies of civil and mechanical, of electrical and metallurgical, of chemical and aeronautical engineers. The only thing that differentiates these groups is techniques. Our very organizations demonstrate our lack of breadth in professional outlook.

Unity and a broader outlook are needed

Efforts have been made in the direction of correcting the situation, but they are feeble. We have our state and national societies of professional engineers, but these are merely associations of individuals licensed (registered) by the state, and such a license is the qualification for membership. We have the Engineers Joint Council, but this is too weak to speak with authority for the profession as a whole. These organizations bear about the same relation to what is needed as the Articles of Confederation between the colonies bore to our American Constitution. If engineering is to get the general recognition it desires, it must first achieve for itself a sense of its own unity and give effective organizational expression to it.

The second shortcoming of engineers is the narrowness, the insularity of their professional outlook on the cultural significance and potentialities of their contribution to life. The nature and seriousness of this limitation can best be made clear by illustration.

The developments of the industrial revolution have made it necessary to have recourse in the modern world to large organizations. To be truly effective, these demand cooperation. Furthermore, I do not mean coordination. Coordination is imposed from above; cooperation is generated from within. The work of the engineer has made cooperation essential, although it would be better to say that the essential thing is coordination secured through cooperation. Meanwhile, within the organization, the engineer is in the best possible position to foster, develop, and inspire cooperation. He can do this in countless uncomplicated ways, by taking advantage of the fact that in industry the human and the technical factors are not segregated, but are intimately, indeed inextricably, interwoven. This fact makes the good engineer by far the most effective instrument of personnel relations. Explaining to the worker why this digester needs to be operated under pressure and that one under vacuum can do more to arouse the interest and enthusiasm of the worker than the efforts of all the psychologists in the world. (Let the engineer make sure, however, that he knows his psychology!) Moreover, in giving the explanation, the engineer has the extraordinary advantage of being recognized as qualified to speak in a tone of assurance, as one having authority. This in turn can become the starting point for getting the worker to understand his own relation to the department in which he works, to his company, of which that department is a part, and finally of his company to the community and the whole social order. From here it may perhaps be possible to get him to recognize the organization of which he is a member as no mere money-making machine, but as making its contribution to the public interest and public welfare and to the enrichment of the common life.

Individual is not just a cog in the wheel

We are told that in modern industry the individual is submerged and lost in the mass. This is not true where the individual can see his relation to the whole. The difficulty lies in the fact that few individuals have that much imagination and vision. What the individual needs is professional help, but to be effective, that help must be at the grass-roots level. This is exactly where the engineer, particularly the engineer in line work in industry, can make the contribution which in my opinion cannot be made equally effectively by any other group. He can lay the basis for a cooperation which, far from stultifying or limiting the individual, can develop for each individual a finer, richer personality than can be achieved in any more isolated environment. Organization is not inherently evil.

If we could once even approach such a goal we would start the transformation of our civilization. The individual could develop a sense of personal achievement through his contribution to the work of the organization, of creativity through helping to enhance the efficiency, both material and hu-

man, of his group, and of loyalty to both his organization and his group within it, because of the degree to which they multiply the effectiveness of every effort of his own. To appreciate the significance of these possibilities, one must remember that these emotions are among the deepest sources of satisfaction to the human spirit, and that in modern industrial organization we have the chance to extend these satisfactions no longer only to the few, but to the many.

What I have said will make clear why I look upon most of our labor legislation as tragic. It is based upon the premise that the interests of labor and management are divergent and that in consequence, their normal relations must be struggle—either war, or at best, a truce. My own conviction is that their interests are not identical, but convergent, and that in consequence their relations should be cooperative, always subject to the restrictions necessary to guarantee the public interest. Had the engineering profession presented such a point of view to Congress and the public before the passage, for example, of the Wagner Act, that legislation would have been far different from what it was. The engineering profession said nothing. Such matters are no business of the engineer.

Management has done much in the matter of better employee relations, but there is much more to be done. Many programs in employee training are highly desirable and successful, and it is well to note how often engineers have been outstandingly successful in giving them. The trouble is that engineers as such have not taken the initiative in the matter and all too often look on activities of this type as outside their professional area.

If the engineer will harness the human forces latent in industry to enhance the efficiency of his material operations, he will make an ethical contribution to industrial and community life that can bring realization of the ideal of William James of a moral equivalent to war.

Another angle of the same situation is that the cultural value of engineering training and experience is not adequately appreciated either by the general public or by engineers themselves. Although it is true that too many engineers are narrow in their interests and insular in their outlook, this is because they are *poor* engineers. The fact is that the engineering discipline develops habits of mind and attitudes of the greatest intellectual, ethical, and social value. An engineer cannot be professionally successful until he has mastered the art of assembling, appraising, and interpreting the facts in a situation and formed the habit, once his analysis is complete, of reaching wise decisions and taking appropriate action. He must have objectivity of mind and integrity of attitude. He must be able to free himself of bias and prejudice. He must develop an outstanding capacity for analysis. These intellectual habits are important in every area of thought and action.

It is true that the first work of the engineer on any problem deals with the material factors involved. Moreover, the human mind has developed the ability to analyze and interpret the facts in this narrow area far more fully than in other areas of human activity. Nevertheless, when the engineer approaches other areas, despite their far greater complexity and difficulty, his mental habits still tend to stand by him and help him handle the problems of the new situation. This is one of the major reasons for the fact that industry has for years drawn heavily on men with engineering background to assume managerial responsibility. Apparently, this trend is on the increase. All too often, engineers look upon their fellows who have gone into these other types of activity as having abandoned professional work, failing to appreciate to what a degree their competence as engineers has qualified them for the exercise of new responsibilities.

Discipline of engineer reveals itself

ON THE "SUMMIT"

This failure to appreciate the broader significance and value of the engineering type of mind may perhaps explain our deplorable lack of pride in the achievement of engineers in other areas of work. Two recent events offer instructive illustrations of the point. Last year, the International Conference on Atoms for Peace was organized under the aegis of the United Nations by Walter G. Whitman. This conference was unique as a United Nations activity in that the representatives of nations from both sides of the iron curtain came together and cooperated wholeheartedly in making the conference a success. It is true that the conference dealt with problems of science and engineering, rather than with political matters, but the political implications and overtones were inescapable. The success of the conference was due to the consummate skill with which it was organized and conducted. The man who furnished this leadership is the Past President of our Institute. Moreover, I assert that his engineering point of view and experience were crucial factors in giving him the capacity to do the job. However, few indeed are the engineers —even the chemical engineers—whom I have met who knew of his connection with the task or expressed pride and appreciation of his accomplishment as that of a fellow engineer.

IN IRAN

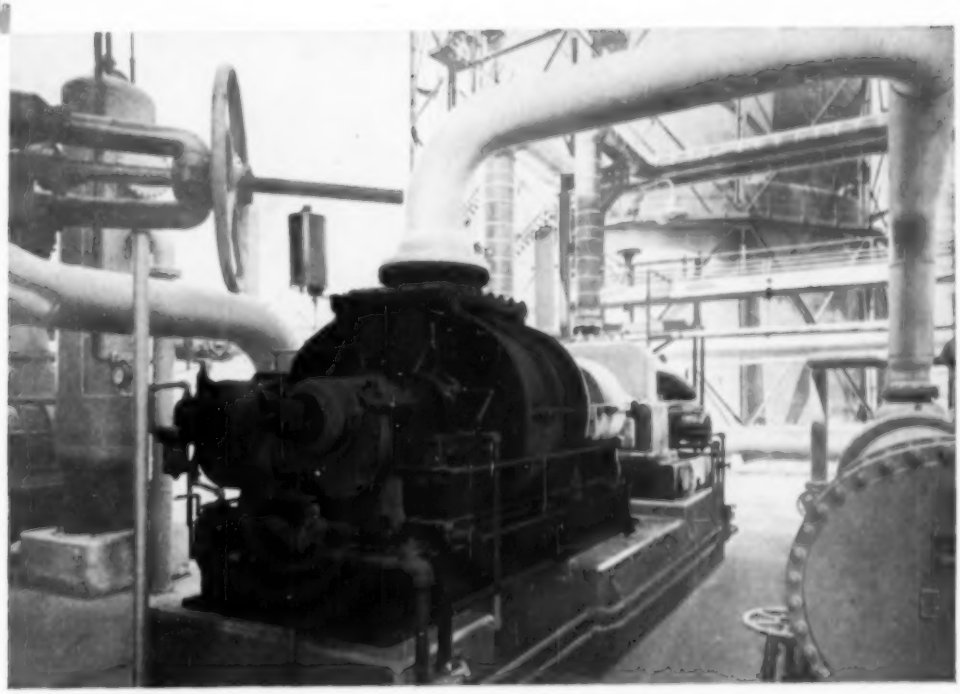
A second episode is the settlement of the Iranian oil imbroglio. Five years ago, the Iranian government kicked the Anglo-Iranian Oil Company out of the country, thereby precipitating an international crisis so serious that it threatened to drive Iran behind the iron curtain. After a long period of bitter and frustrating deadlock, the Iranian government was finally persuaded by the United States State Department to try to negotiate a settlement. The leader in achieving this result was Herbert Hoover, Jr., in the diplomatic service, it is true, but a fellow engineer. Negotiations were conducted by the Iranians with representatives of a group of western oil companies, headed by an executive of one of them. The negotiations bogged down. When they were resumed, the former western head was unable again to assume the responsibility because of ill health, and the leadership was taken over by a chemical engineer, Howard Page. These negotiations resulted in an agreement for cooperative development of Iranian oil fields and operation of the Abadan refinery. The agreement was put into effect, and from that day to this, I, for one, have not seen a single word of newspaper reference to the oil situation in Iran. That is news. Evidently, in Iran, cooperation between East and West starting with mutual agreement based on mutual self-interest is working. Furthermore, that cooperation is an engineering operation. If cooperation of that sort can be secured around the world, the problems of our time are capable of solution. To me as an engineer the distressing fact is that I can count on my fingers the engineers I have met who had even heard of Howard Page.

Engineers must appreciate themselves

Personally, I consider these two achievements outstanding victories of the West in the cold war—indeed, perhaps the two outstanding victories. I am convinced that the men who organized them owed their success in large degree to their engineering discipline. If engineering can turn out a few more men like Walter Whitman and Howard Page, and if engineers can develop the vision to appreciate their achievements, and the pride in them to give expression to that appreciation, perhaps engineering can, after all, develop into a profession.

MATHIESON

For Olin Mathieson



R-C pumps and blowers control air and gas mixing

In the manufacture of ammonia at this large Olin Mathieson chemical plant at Lake Charles, Louisiana, large volumes of hydrogen, nitrogen and air are positively proportioned and compressed by Roots-Connersville equipment.

R-C Gas Pumps are teamed with Rotary Positive Blowers to handle pure hydrogen gas and air for processing into a 3:1 hydrogen-nitrogen synthesis. Another R-C Gas Pump compresses this mixture to supercharge other equipment.

Inherently high efficiency of the famous R-C rotary positive design, extremely low friction loss and extra deep stuffing boxes are a few of the reasons why this equipment delivers maximum performance within rated capacities.

Here is another example of the widespread application of R-C equipment in the process industries. If you have a product or a process requiring handling and accurate control of air or gas, Roots-Connersville engineers will welcome the opportunity to give you the benefit of their long experience. Address your inquiry to Product Development Manager.

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14 x 28 Gas Pump rated 4250 cfm, 830 rpm, 112 Hp

10 x 18½ Blower rated 1770 cfm, 830 rpm, 37.6 Hp

The 14 x 28 Gas Pump and 10 x 18½ Blower are direct-driven in a single assembly.

The 22 x 29 Gas Pump functions as a supercharger for the 3:1 hydrogen in nitrogen gas mixture.

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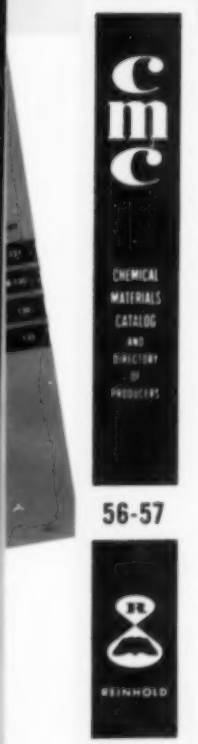

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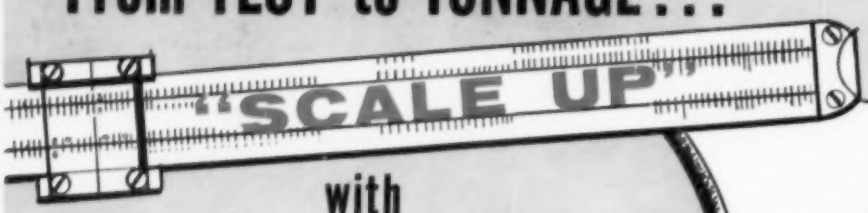

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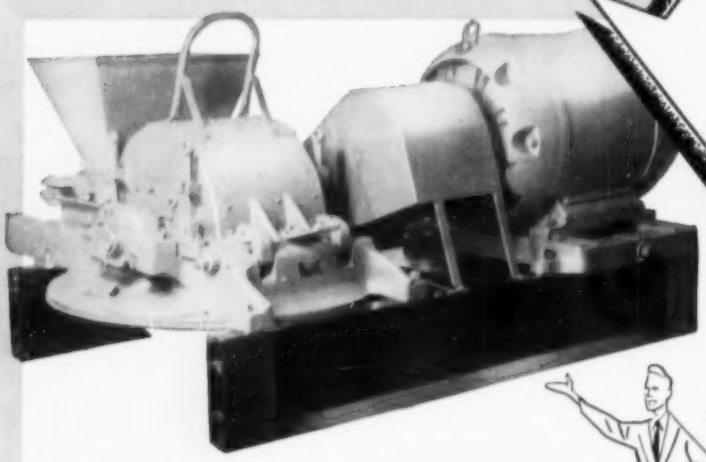
THE BANTAM PULVERIZER is a complete miniature grinding plant, perfect for pilot plant and experimental work. Easy and economical to operate, the BANTAM utilizes a ¾ or 1 hp motor, and has an average capacity of 75-100 lbs. per hour.



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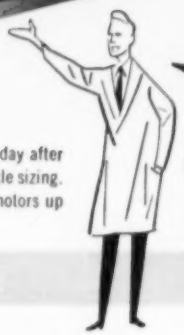

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An Achievement of
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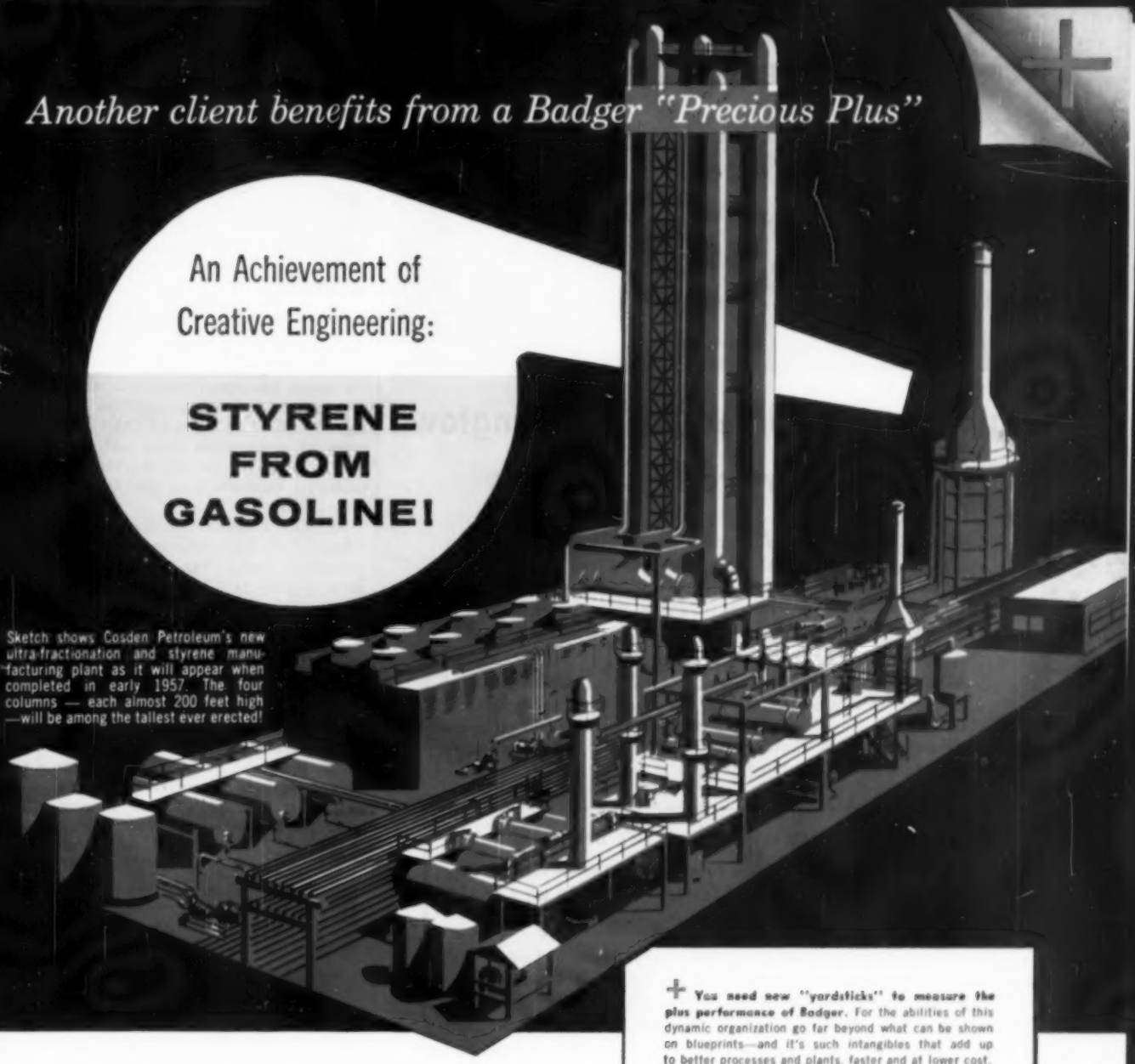
STYRENE FROM GASOLINE!



Sketch shows Cosden Petroleum's new ultra-fractionation and styrene manufacturing plant as it will appear when completed in early 1957. The four columns — each almost 200 feet high —will be among the tallest ever erected!

The plant that "couldn't be built" now under construction

At Cosden's Big Spring, Texas, refinery, Badger is erecting the first plant ever designed for the recovery of ethyl benzene by distillation. The process *first* became commercially practical when Badger Engineers developed Ultra-fractionation.

Now, instead of marketing catalytic reformer effluents as mixed solvents, this new distillation process will make it possible for the client to produce a pure product with a far higher profit margin.

This achievement in *Creative Engineering**, like all intangibles, can never be shown on the blueprints. Yet it is the "Precious Plus" in Badger's performance that is making Cosden's plant possible!

Other leading companies, too, find Badger's *plus* in performance of precious advantage — whether their need is design, engineering or construction. How else explain the unusual growth Badger is enjoying?

+ You need new "yardsticks" to measure the plus performance of Badger. For the abilities of this dynamic organization go far beyond what can be shown on blueprints—and it's such intangibles that add up to better processes and plants, faster and at lower cost.

*Creative engineering . . . whether your process problem is common or complex, Badger engineers solve it with fresh thinking that frequently produces new efficiencies, unexpected savings.

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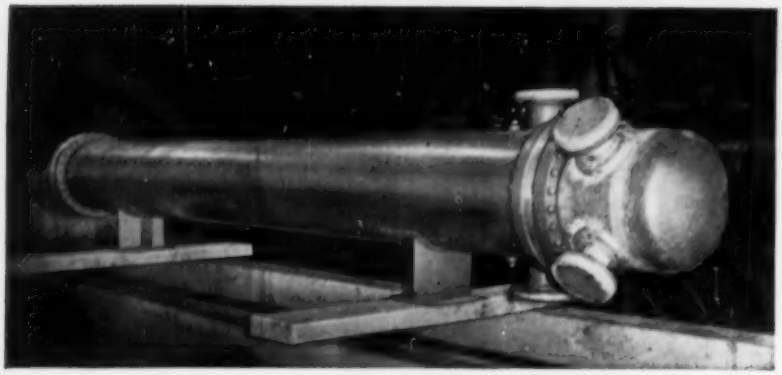


Aluminum translated by Downingtown ...metallurgically speaking

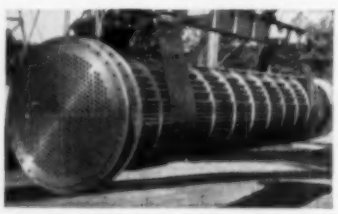
The special problems of aluminum welding and fabrication are another metallurgical "language" that has been expertly mastered at Downingtown. In this fixed-tube sheet heat exchanger unit, aluminum heads, tubes and tube sheets have been combined with a carbon steel shell to meet specific service conditions.

When heat transfer specifications call for aluminum...or aluminum bronze, nickel, copper, stainless steel, or almost any clad or alloy...you'll find the metallurgical idiosyncrasies are well understood at Downingtown. Send for our informative booklet on heat exchanger design.

SPECIFICATIONS OF THE UNIT

Materials: Aluminum Tube Side and Carbon Steel Shell
Tubes: 192 Alclad Tubes, ¾" O.D. x 16 ga. x 14'0" L
Shell Diameter: 18"
Over-All Length: 16' 1"
Design Pressure: Shell Side, 100 psi—Tube Side, 200 psi
Test Pressure: Shell Side, 150 psi—Tube Side, 300 psi
Design Temperature: Shell Side, 250° F.—Tube Side, 350° F.
Code Stamped: Inspected by Purchaser and Hartford

Putting the finishing touch on another heat exchanger unit built by Downingtown. We build to your specs, or do complete design.



We rolled type 329 stainless steel tubes into types 316 and 304 stainless tube sheets to make this stainless steel replacement bundle.

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About our authors

The Pittsburgh symposium on "Explosions in Chemical Engineering" gives us this month three papers by outstanding experts in the field. **Irving Hartmann** (*Recent Findings on Dust Explosions*) is Chief of the Branch of Dust Explosions, Division of Explosives Technology, U. S. Department of the Interior. Physicist Hartmann has done considerable work with industrial dust explosions, including evaluation of explosibilities of all types of combustible dusts and preventive measures, has also worked and published extensively in the field of mine safety.

Hartmann

M. G. Zabetakis (*Flammability Limits of Hydrocarbons at High Temperatures and Pressures*), who is Chief of the Branch of Gas Explosions, U. S. Bureau of Mines, is an expert in gas explosion technology, has done considerable work with ASTM committees in this field. With team members **R. E. Kennedy** and **G. S. Scott,** he has published extensively; all three are currently engaged in further research with the Bureau.

Zabetakis

J. H. Burgoyne, who contributed the paper on *Mist and Spray Explosions*, is a British engineer with a wide reputation in this field, is now teaching at the Imperial College in London.

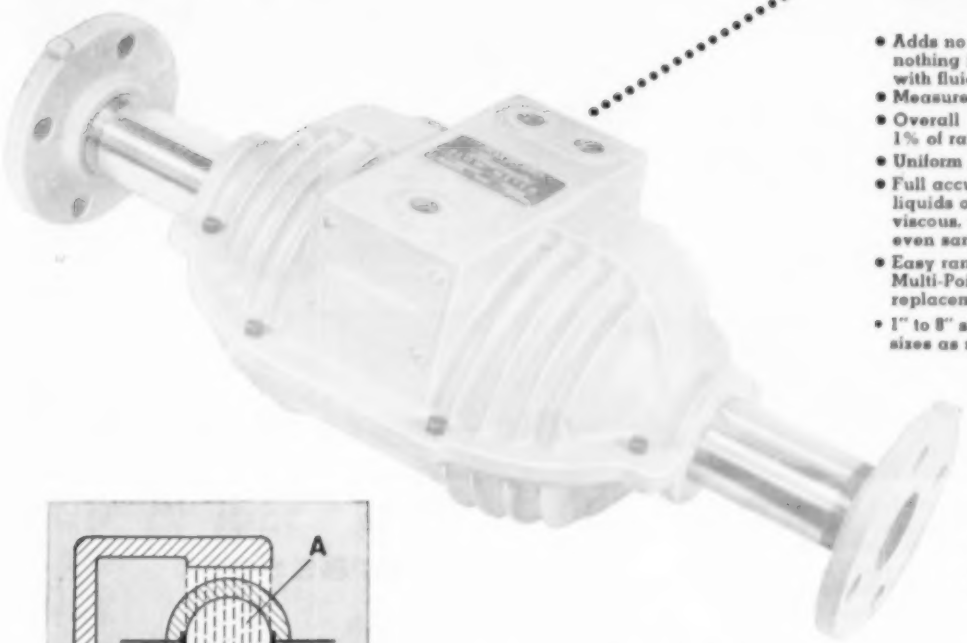
Burgoyne

Continuing *CEP's* presentations in the field of oxygen plant safety is this month's article on *Oxygen Plant Safety Principles* by **Clyde McKinley,** Director of Research at Air Products, and **Franklin Himmelberger,** also with Air Products. McKinley is well-known to Institute members through the two symposia he has presented in the low temperature field, is currently working up a third for presentation at the coming Baltimore Meeting in September. *CEP* is particularly pleased to be able to present this important new data which will have considerable impact on safety considerations for operators and designers of oxygen plants.

Since 1943 with National Carbon Company, **W. M. Gaylord** (author with **M. A. Miranda** of the article *Falling-Film Hydrochloric Acid Absorber*) is special projects engineer

(*Continued on page 32*)

NOW! a flow meter with no flow restrictions!



- Adds no pressure drop — nothing inside pipe to interfere with fluid flow.
- Measures fluid velocity directly.
- Overall accuracy better than 1% of range over entire scale.
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- Easy range change — either by Multi-Point Switch or range coil replacement, as preferred.
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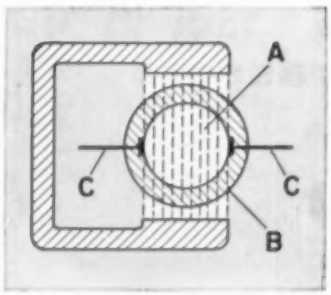

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The Foxboro Magnetic Flow Meter operates on the same principle as a power generator. A magnetic field (A) is maintained through a standard pipe section (B) of stainless steel or other non-magnetic material. This pipe section is lined with Kel-F® or other insulating material. Liquid passing through pipe acts as moving conductor, generating an electric voltage which varies in proportion to liquid's average velocity. Flush electrodes (C) in pipe wall "pick up" this voltage which is recorded in desired flow units by Dynalog Electronic Recorder or Controller.

This premium-performance meter measures *magnetically* the flow rate of virtually any liquid except hydrocarbons. It completely ignores such common metering headaches as turbulence, suspended solids, and variations in conductivity, density, and viscosity. It even measures reversing flows.

Installation is simple. The magnetic spool piece connects into the line like any equivalent length of pipe — no seals, purges, meter runs, or straightening vanes required. Connects by 2-conductor cable to remote Dynalog Electronic Flow Recorder.

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Foxboro Magnetic Flow Meters are already in use on such widely different liquids as beer, sand-and-water, rosin size, rock-and-acid slurry, viscose, and highly corrosive liquid detergent. Find out how this precise, troublefree flow meter can help *your* processing. Write for complete details.

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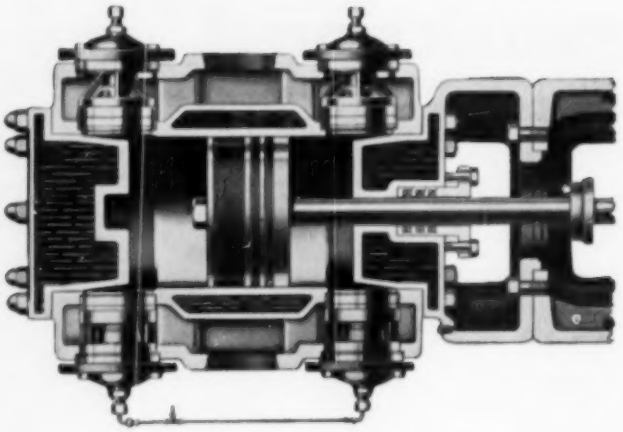
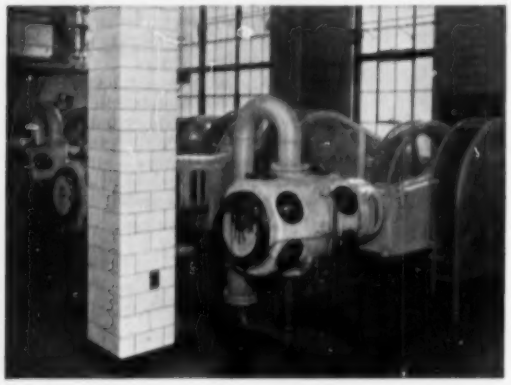
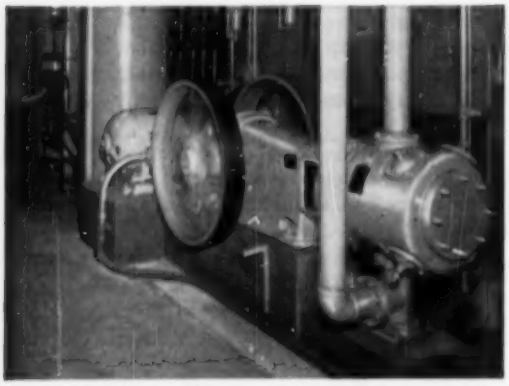
NL Channel Valves are designed specifically for non-lubricated service. Carbon guides protect channel ends and special Teflon strips protect channel interiors and spring ends from metal-to-metal rubbing and wear.





Installed in a large brewery in 1933, this Ingersoll-Rand ES-NL compressor was the first unit ever built with non-lubricated cylinders. It is still in daily service, providing the clean, oil-free compressed air which is vital to product purity. Three other ES-NL compressors, installed since then, are shown in the background.



One of four ES compressors with NL cylinders, supplying oil-free air in the manufacture of super-precision instruments and aircraft ball bearings.

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In process and manufacturing plants all over the world, the problem of oil contamination in compressed air and gases has been successfully solved by the application of Ingersoll-Rand ES-NL compressors.

The unique NL cylinder design provides compression without oil lubrication—through the use of graphitic-carbon wearing and pressure rings. The ability of these compressors to deliver clean, oil-free air and gas, in continuous, heavy-duty service, has been thoroughly proved in every field of application.

If you have an application where oil-lubricated compressor cylinders cannot be used, ask your Ingersoll-Rand representative about the ES-NL compressor, sizes 5 to 150 horsepower—other Ingersoll-Rand NL compressors to 1000 hp.

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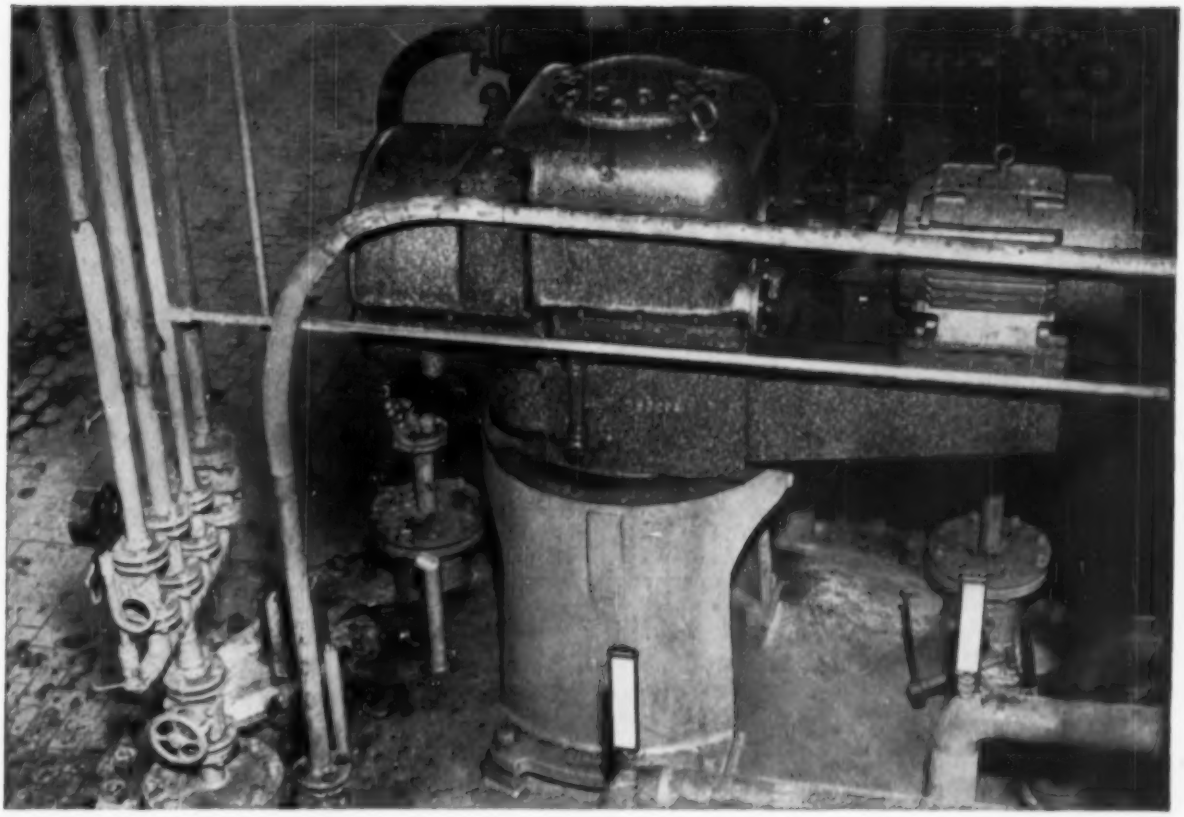
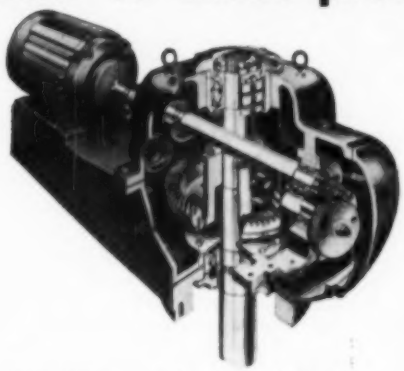


How to meet process mixing changes on the job



Philadelphia gear reducers for turbine and paddle-type fluid mixer drives have been meeting the most exacting specifications of major processors for many years. Because we now manufacture every major component of the new Philadelphia Fluid Mixers, except motors, bearings and mechanical seals, we offer the most integrated fluid mixer design, specifying, manufacturing and servicing facilities available.

Here's how one large chemical processing plant meets widely fluctuating batch to batch mixing changes quickly and easily . . . and lowers costs at the same time.

Their problem was twofold. First, to correctly mix sizeable quantities of highly corrosive material with abruptly changing viscosities without exceeding the rated capacity of the mixer drive. Secondly, to change motors and mixing speeds on the job readily and simply with minimum downtime expense.

The problem was quickly solved with the installation of a 3820 "packaged" Philadelphia Mixer. This mixer more than meets requirements for half speed operation at 7½ HP and full speed operation at 15 HP. Designed and built with generous service factors, the unit provides ample drive capacity for peak loads . . . assures long, quiet, trouble-free operation. All drives are AGMA rated.

Easily accessible helical change-gear set allows ready selection of 14 different standard speeds from 20 to 280 rpm. Service-rated motor is readily replaceable for any operating condition or routine maintenance. Only a few simple tools are necessary for speedy changeover.

Philadelphia "packaged" Mixers are designed for maximum adaptability to all fluid Agitation applications. Standardization, high-production and complete control of all manufacturing by Phillie Gear assures you outstanding mixer performance at minimum cost.

Take a tip from this well-known chemical processor and see how you, too, can obtain maximum pressure vessel mixing results with new Philadelphia Mixers.

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COOLING TOWER POWER GOES HIGH HAT

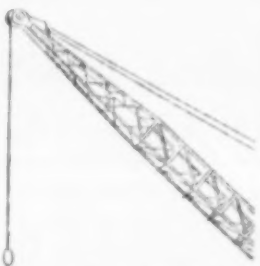
Putting the fan cylinder to work, making it a functional part of the tower, is Marley's latest achievement that brings a new look to industrial cooling towers. As an integral part of Marley tower power the new VL (vertically laminated) Fan Cylinder* has a job to do beyond merely discharging exhaust vapor at high elevation to minimize the hazard of fogging . . . IT AMPLIFIES FAN EFFICIENCY AND COOLING PERFORMANCE.

The distinctive VL contour is dictated by tested, scientific design that increases air volume by recovering velocity pressure . . . simply making more air do more cooling. To engineers specifying new equipment, this is an added and important assurance of Marley's ability to deliver full, testable performance on every cooling tower installation.

As modernization equipment for existing towers, VL fan cylinders positively reduce water cooling cost in any of three ways:

1. **Cooling a greater volume of water at specified temperatures without added fan horsepower.**
2. **Cooling specified volume of water at specified heat load to lower temperature without added fan horsepower.**
3. **Reducing required horsepower for any specified performance.**

VL fan cylinders are safe, sturdy units. Laminated construction provides a rugged design which assures long, trouble-free service. Bolted laminated bands and integral truss bracing result in a unitized packaged assembly independent of tower framework for structural stability. Safety to operating personnel is provided by the strength and height of the cylinder and by the large access door permissible only in VL design.



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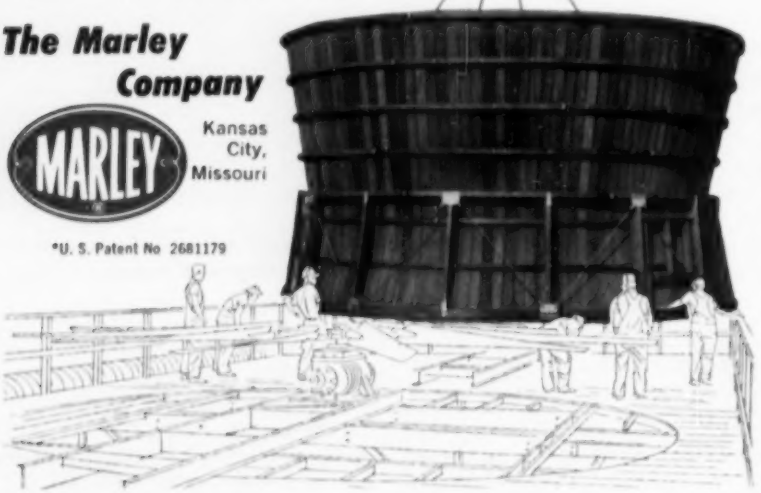

About our authors

(*Continued from page 28*)

in the Chemical Products Sales Department, Cleveland. He is now doing special process engineering work with carbon and graphite materials of construction for heat exchangers, pumps, and absorption equipment as applied to corrosive chemicals. Miranda, staff assistant in the same department, is similarly engaged.

From the just-concluded White Sulphur Meeting **R. L. Kittle** of Shell Chemical (with **H. A. Mitchell**) presents a candid view of *The Future of Raw Materials for the Organic Chemicals Industry*. Kittle has been with Shell since 1931, except for a stint of war-time duty with the Office of Rubber Reserve, now keeps on eye on chemical industry trends from his advantageous position as manager of Shell's Manufacturing Operations Department. This forecast should enable long-range planners to benefit from his experience.

Kittle

H. E. O'Connell (*Design of Perforated Plate Fractionating Towers*) has been fifteen years with Ethyl Corporation, is now project manager in the Engineering Department at Baton Rouge. Present project: working up an expansion program in ethyl chloride and vinyl chloride production. **G. A. Hughmark,** who presented the paper in Boston, is a 6-year veteran with Ethyl, is an assistant in the Chemical Engineering Department, Baton Rouge.

Hughmark

H. C. Schutt (*Ethylene by Computer-Design of Ethane Pyrolysis Reactor*), is in private consulting work in Boston, specializes in process design for the petroleum industry. Coauthor **R. H. Snow** is a research chemical engineer with Armour Research Foundation at the Illinois Institute of Technology, presently finds his talents diversely employed on a variety of industrial and government research projects, some in mathematics, others in process and product development.

A. R. Dudley (*How Control Over SO_2 Emission Reduces Air Contamination*) is in the Technical Service Division of Humble Oil at Baytown, Texas. An ardent proponent of antipollution measures, Dudley believes that industry has a moral obligation to the public to keep atmospheric and other pollutants at a minimum.

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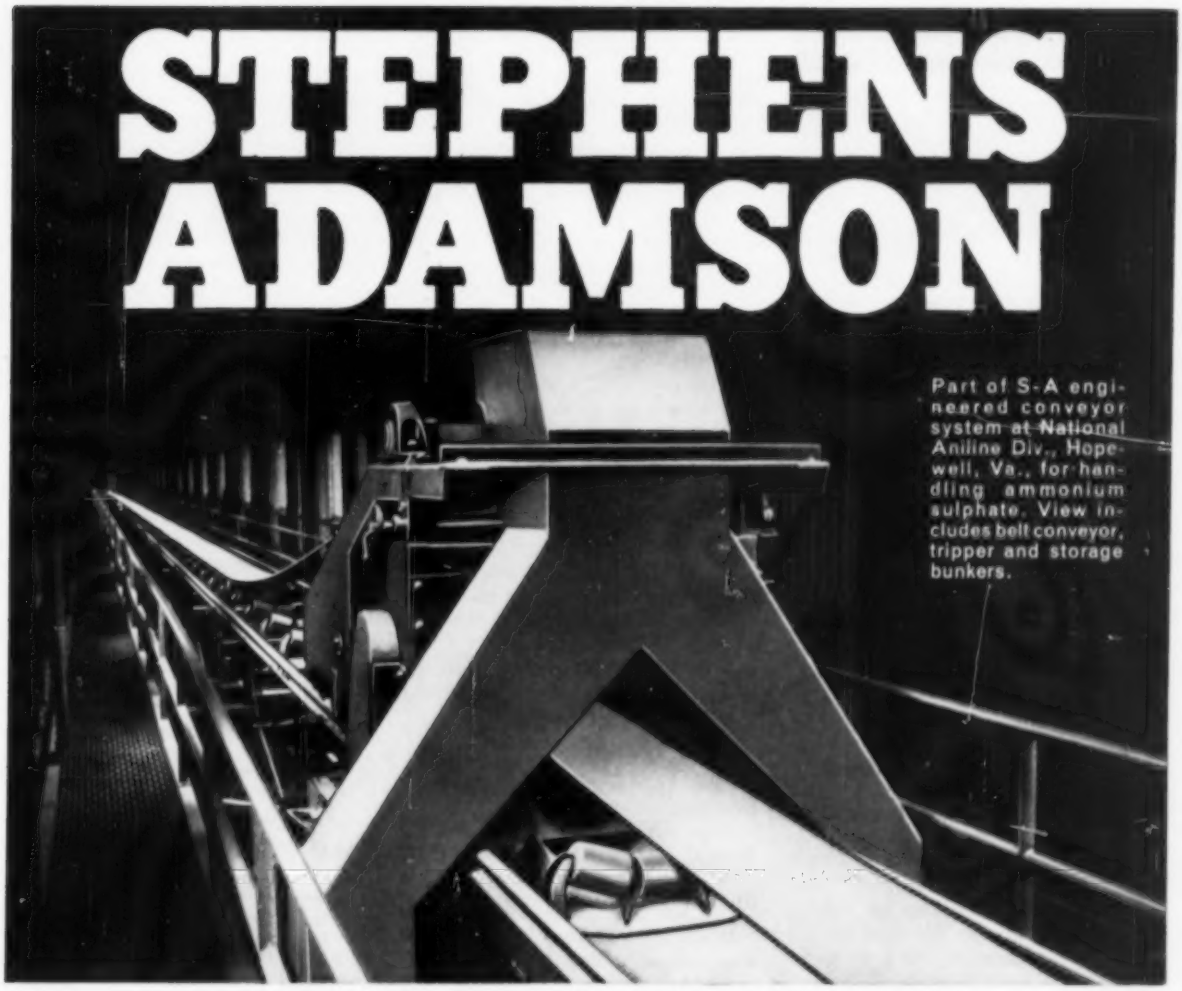

Part of S-A engineered conveyor system at National Aniline Div., Hopewell, Va., for handling ammonium sulphate. View includes belt conveyor, tripper and storage bunkers.

lower cost chemical processing thru better bulk material conveyor systems!

One of the basic aims of the chemical industry is improvement of processing. For many years, STEPHENS-ADAMSON has aligned its efforts with this aim by providing better, more scientific methods of bulk material movement in the processing plant.

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Letters to the editor

The Executive Yoke

I have read with considerable interest the recent articles in *CEP* on management problems, executive training, and group management techniques and would like to call attention to another facet of the position of the executive in the process industries.

There was a time when men with plenty of imagination, some courage, and a little education could convince bankers to back their ideas—ideas which they would then build into successful enterprise. There are still many men today who have these abilities and are trying to join U. S. industries, but they are not given proper consideration.

American industries need specialists up to, and including, top executives, with the result that the development of broad executive abilities has been unintentionally curtailed. This is seriously hampering our industrial growth. Industries are already engaged in managing their businesses around the thesis that an individualist on the management team does not "fit in," and these men are thus driven into business for themselves. When new executives are screened, they are examined psychologically, by written or oral tests, to determine whether or not they can "fit in." Employers spend far too much time looking for stability and conformity in the hard-driving person. In many instances, when circumstances force a company to search outside the organization to fill a serious gap, they want hard-driving, ambitious executives with new ideas, leadership, clear-cut and positive thinking, and also the ability to train junior executives. When they have found a man through professional executive recruiters or management consultant groups, they find it very difficult to bring him into the organization after extensive personal interviews because his personality and his company test aptitudes do not conform to their standard. They do not realize that this very insistence on conformity is probably responsible for their present position. They want the accomplished individualist, but destroy the opportunity of signing him up by subconsciously seeking out the average "Mr. Ivy League" or "Mr. Madison Avenue" executive. The average executive has been defined as "the best of the worst and the worst of the best." Industry will not survive this type of thinking, for *average* is just not good enough.

Many companies have recruited qualified executives and immediately subjected them to operating committees which are, in most cases, like an ox yoke to the outstanding capable individual. The idea that two heads are better than one in such cases is ridiculous, for politics play an important part in the management of most businesses, and on many of these committees are men who serve not because of ability, but because of stock holdings or favoritism. Ideas are curtailed by the lack of imagination on the part of three or four committee members when one man could doubtless do the job if not handicapped by constant political problems. Very few companies managed by these groups are attractive to men with outstanding abilities.

Cooperation is, of course, necessary and every company must have a full degree of it in order to be successful. But cooperation can be had just as easily through competent qualified administrators—in many cases much easier than through a group of people who are improperly informed, have very little or no imagination, and are prone to let good ideas die on the discussion table. The force of one competent individual's ability can do more for a corporation than all its groups, committees, teams, or what have you.

This situation has come to our [firm's] attention as a result of the vast number of executives being recruited in today's market, and our own consulting efforts in that field. We have looked for and have found top-qualified and exceptional people who without a doubt have the requisite abilities. We have referred them to management groups and had them rejected because they were "too aggressive," not 'yes' men, or expressed their own ideas of management (the most severe criticism)—yet these very qualities were in the original specifications for the job. When it is concluded that a candidate does not "fit in" with the *status quo*, or that he is unable to accept it as is, this is also cause for rejection. Oftentimes these executive candidates are forced to compromise their thinking and enter companies that do not suit their abilities. Result: the present management continues to be dissatisfied with their "average" executives and remains mediocre in their production.

A solution to this problem can be found only when it is recognized that great companies were not built by 'yes' men, by men in gray flannel suits, or by business school graduates selling sheepskins, but by men with imagination and the courage of their convictions.

E. A. Butler
E. A. Butler & Associates, Inc.
Philadelphia, Pennsylvania

Short-Handed on Instrumentation?

While at Heidelberg University last Fall, attending the Fachtagung "Regelungstechnik," an international meeting of some 800 instrumentation specialists, I acquired certain information about what the U.S.S.R. is doing in connection with the training of control engineers. This information has since given concern not only to myself, but also to a number of acquaintances in the field of process control with whom I have discussed the matter.

I believe that many readers of *CEP* are sufficiently interested in where we are going to get the trained men for the automation of our chemical process plants that they too would want to know what the Russians said at Heidelberg.

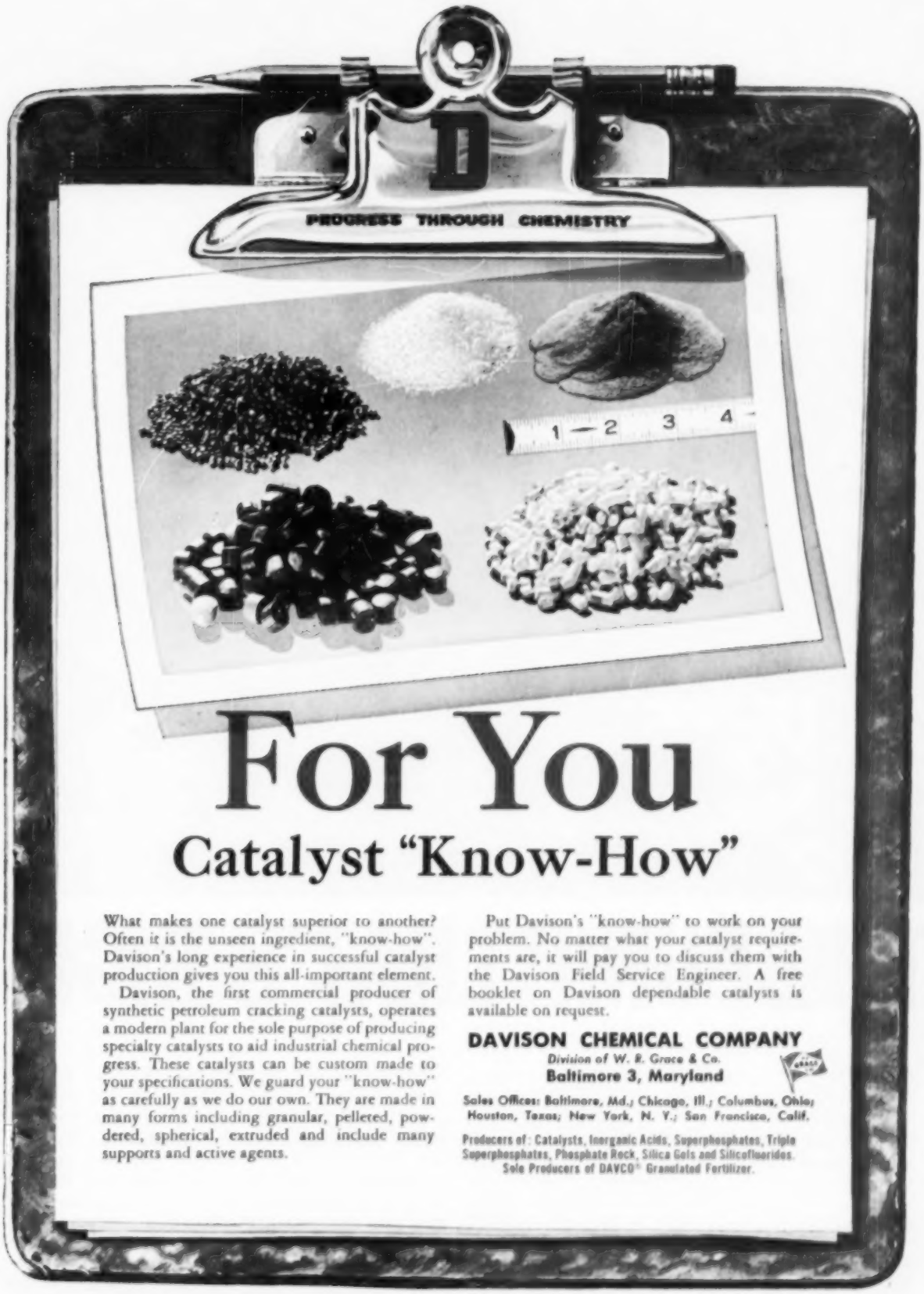
During an informal dinner held at the conference (with two other Americans, three Germans, three Britons, and three Russians in attendance) there developed a non-political discussion of the Russian educational system. The Russians present were professors —faculty members of the Institute of Automatics and Telemechanics of the U.S.S.R. Academy of Sciences in Moscow. One holds a position corresponding to department head in a U. S. school of engineering. In the course of the discussion, the Russians confirmed the estimates of U. S. educators that the Soviet Union is graduating about 75,000 engineers of all types annually, and that about 75 per cent of the U.S.S.R. college population is enrolled in engineering courses, compared with only 7 per cent of U. S. college students.

The discussion continued on into the field of process control, with the Russians bringing out the information that the U.S.S.R. has graduated about 5,000 control engineers a year in recent years—which is about 10 times the number graduated in the U. S.!

When one considers that there are no degree-carrying courses in instrumentation in the U. S., and that when trying to hire a control engineer one must generally look for a chemical engineer who has ham radio as a hobby in order to get a suitable combination of process and electronics knowledge, one can readily grasp the significance of the Russians' remarks.

Russia appears to be training all the instrument experts it needs.

Dave M. Boyd, Jr.
Universal Oil Products, Inc.
Des Plaines, Illinois



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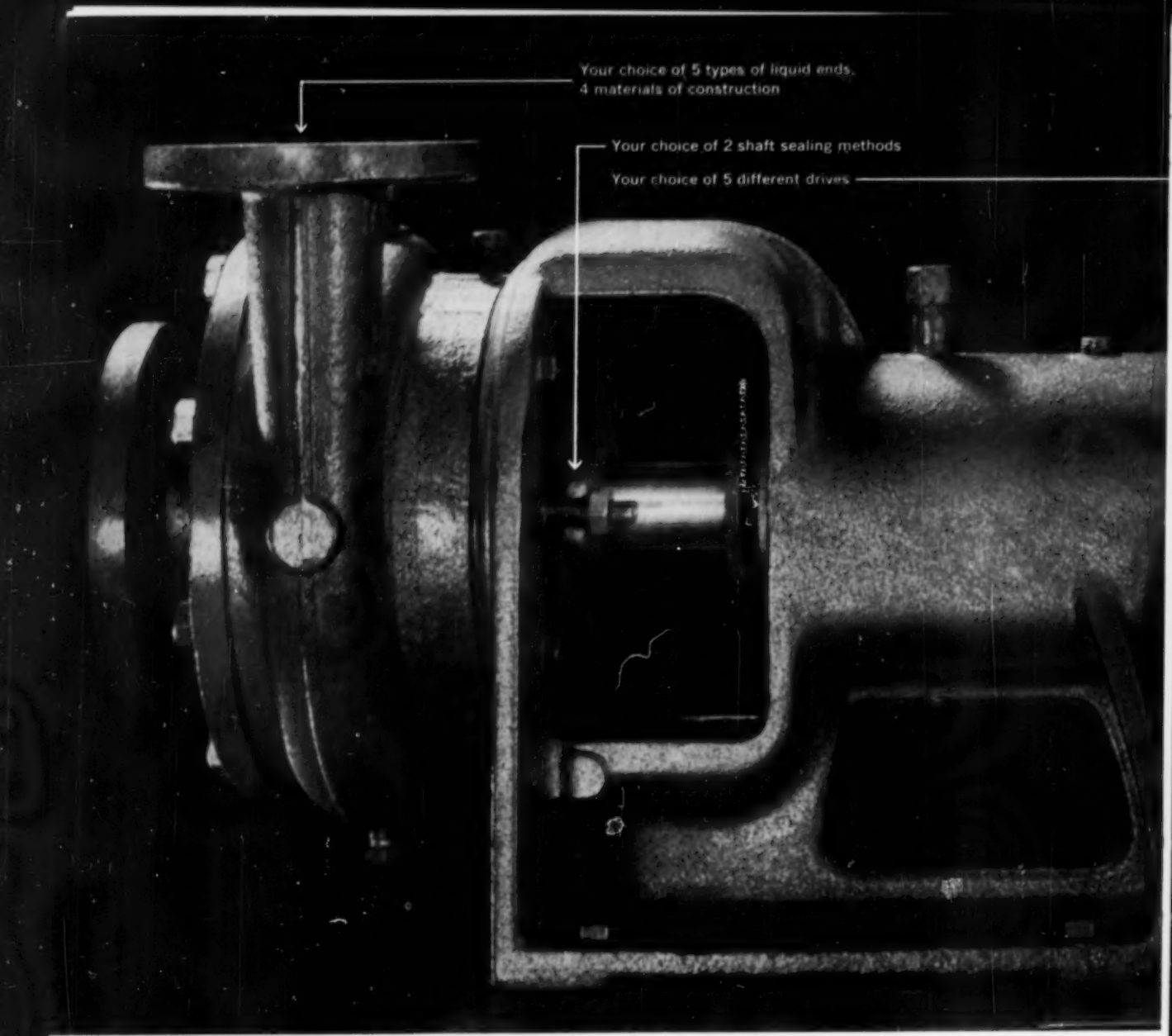
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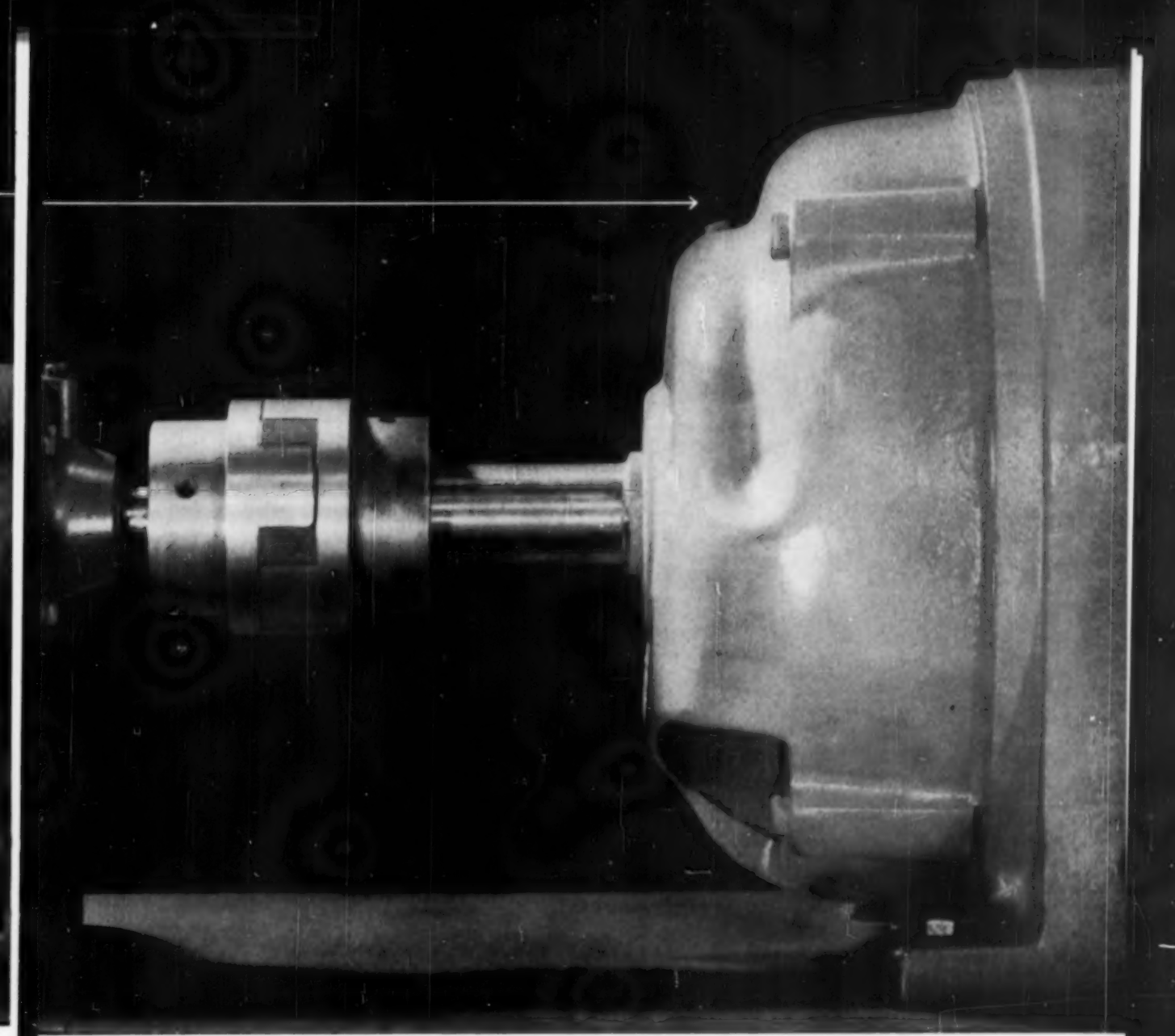

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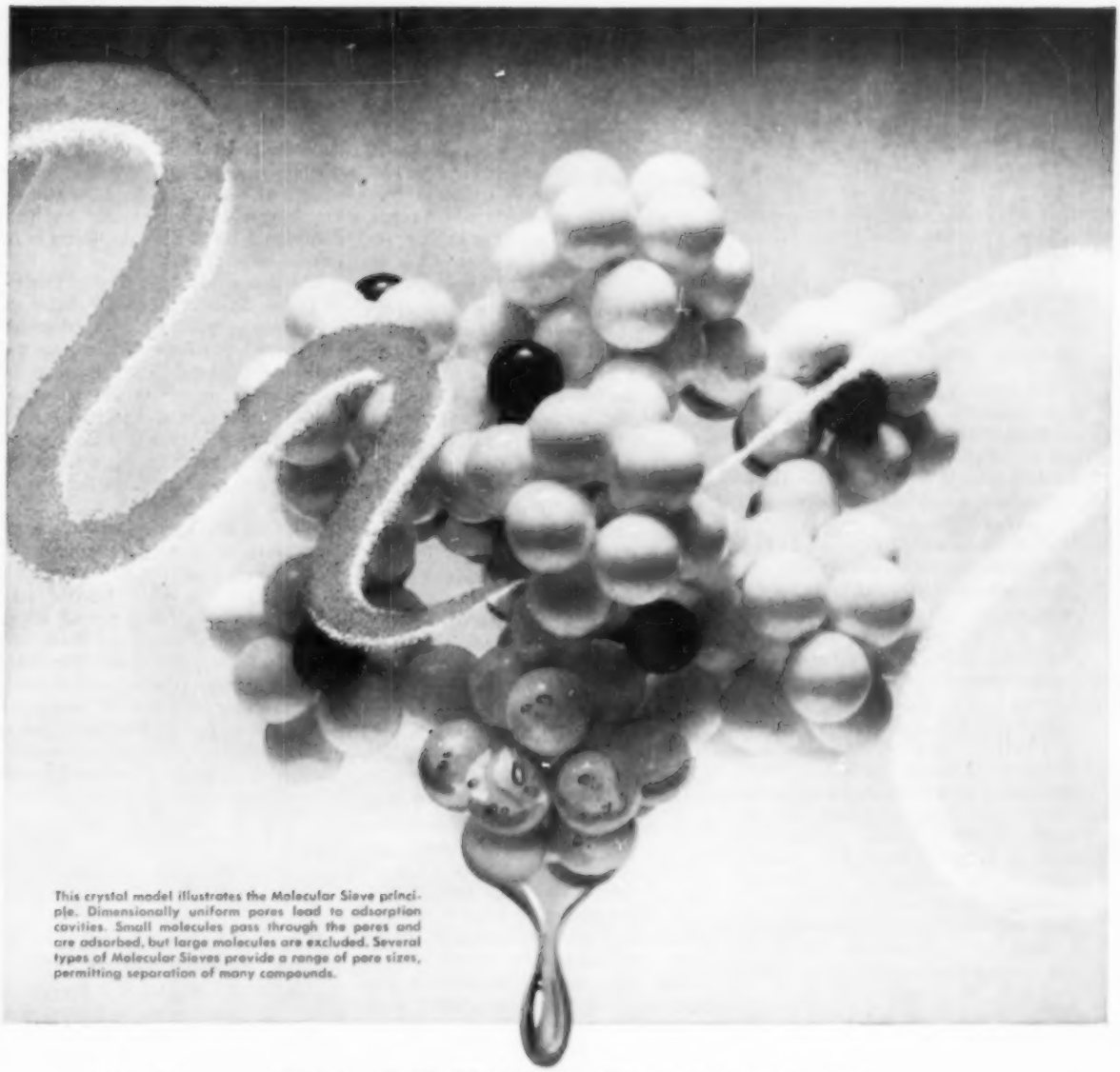

This crystal model illustrates the Molecular Sieve principle. Dimensionally uniform pores lead to adsorption cavities. Small molecules pass through the pores and are adsorbed, but large molecules are excluded. Several types of Molecular Sieves provide a range of pore sizes, permitting separation of many compounds.

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Typical uses for Molecular Sieves are the separation of n-paraffins from iso-paraffins and cyclics . . . extraction of olefins from refinery streams and top gases... removal of catalyst poisons from olefins... sweetening of natural gas and reformed hydrogen... purification of annealing gases.

For a descriptive booklet, "Molecular Sieves for Selective Adsorption," write Dept. XX-00, Linde Air Products Company, A Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y.

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Marginal notes

High Speed Aerodynamics and Jet Propulsion — Combustion Processes. Vol. II.

Edited by B. Lewis, R. N. Pease, and H. S. Taylor. Princeton University Press, Princeton, New Jersey (1956), 662 p., $12.50.

Reviewed by Alexander Weir, Jr., Department of Chemical and Metallurgical Engineering, University of Michigan, Ann Arbor, Michigan.

The primary purpose of this volume is to acquaint engineers with current combustion theories and their application to jet propulsive devices. Considerable emphasis is placed on the chemical aspects of combustion and the subject matter of the entire book is treated from a fundamental viewpoint. This book is recommended to chemical engineers who are interested in high-speed reactions as well as to workers in the field of combustion. The sections on chemical kinetics, thermodynamics, and nuclear reactions should be of general interest.

Although this is the second volume in a twelve-volume series, the book is self-sufficient in that specific references to material presented in the preceding volume (on thermodynamics) are not made. Twenty different authors contributed to this volume with surprisingly little duplication of material. Although the literature references, figures, and equations are numbered separately for each section (there are ten equation 2-1's), an adequate index and table of contents is included.

The first of the six parts of this volume is entitled *Thermodynamics of Combustion* and includes sections on high-temperature equilibrium, expansion processes, and computational techniques. All receive a rigorous treatment and the discussion of two phase flow in nonequilibrium expansion should be extremely valuable to engineers.

The second part of this book is devoted to a fundamental treatment of chemical kinetics. It is not restricted to combustion problems, although oxidation reaction rate data are presented. Part 3 is entitled *Flame Propagation in Gases* and includes sections on mechanics of reaction continua, combustion waves in turbulent and nonturbulent gases, and diffusion flames. It is in this part of the book that most of the current combustion theories are presented as well as the experimental data on ignition, flame propagation, and flame stability. The next part contains sections on fuel droplet atomization, evaporation and combustion, combustion of solid fuels including dusts, and four chapters on rocket propellants, both liquid and solid.

Part 5 is a discussion of detonation processes in gases, liquids, and solids with emphasis on the last named. The authors of this section reside in Ireland and Scotland, which may account for the inclusion of a large number of foreign references and omission of recent work done in this country—for example, papers at the several symposia on Detonation sponsored by the Office of Naval Research. Other omissions include the classification of detonations into strong, Chapman-Jouguet, and weak waves, and the use of detonation Mach number. These omissions in gaseous detonation discussions are, however, more than counterbalanced by the excellent discussions of the theory of solid explosives.

The last part is entitled "Energy Production by Nuclear Reactions." It is an excellent description of the fundamental particles of nuclear physics and their reactions with various chemical elements. However, this part seems out of place in this volume on combustion processes.

In the reviewer's personal opinion, the purpose of this volume would have been better achieved if Part 6 had been omitted and Part 5 had been expanded to include more work on gaseous detonation. The addition of more material on combustion spectra (only three pages are devoted to this) would also have been beneficial. However, considering the wealth of material from which the editors and authors were forced to choose, it is remarkable that such an excellent treatment of combustion was achieved in a single volume. It is the best available volume on the subject.

Design of Piping Systems, Second Edition. The M. W. Kellogg Company.

John Wiley & Sons, Inc., New York, Chapman & Hall, Limited, London (1956), 365 p., $15.00.

Reviewed by C. L. Mantell, Chairman, Department of Chemical Engineering, Newark College of Engineering, Newark, New Jersey.

Some of our theoretical chemical friends have described chemical engineers as "glorified . . . designers of liquid transportation and transmission systems and sewers." Perhaps it is true that a large share of our process industries plants in their continuous operation do result in glorified piping systems, highly complex, operating over wide ranges of temperature, pressure, and performance with ability to resist the corrosive and destructive influences of reactants and the materials being processed. What our theoretical chemists may fail to appreciate is the necessity of structural stability of such complicated piping systems. This structural stability is incorporated in the design, where emphasis on flexibility analysis of critical systems is of intense importance.

The first edition (1941) of "Design of Piping Systems" made available an adequately organized, comprehensive analytical method for evaluating the stresses, reactions, and deflections in an irregular piping system in space, unlimited as to the character, location, or number of concentrated loadings or restraints. Obviously the method included accurate thermal expansion analysis.

With the development of more complex units, with increased pressures, temperatures, and structural complexities, larger pipe sizes, heavier wall thicknesses, and greater use of alloys as constructional materials, there was need for adequate piping flexibility analysis, particularly for critical service, involving the over-all economics of erected piping by correlating potential fabrication, materials, and operating savings necessary to stem the tide of increased engineering costs.

Fluid Flow in Practice, J. R. Caddell.

Reinhold Publishing Corporation, New York (1956), 119 pages, $3.00.

Reviewed by Leo Friend, The M. W. Kellogg Company, New York.

This book contains a collection of seven papers presented in Philadelphia in May, 1955, under the auspices of the Philadelphia-Wilmington Section of the American Institute of Chemical Engineers, and the Department of Chemical Engineering, University of Pennsylvania. The subject matter covers a brief summary of the basic relationships, followed by practical discussions on planning of piping systems, choice of valves, pumps, and flow meters. The concluding chapters cover material on the operation and maintenance of fluid-flow equipment and the trends in fluid-flow research.

From the 119 pages contained in this book it is readily deduced that the treatment of each subject cannot be comprehensive, but can merely be a review of the basic principles needed to guide the neophyte engineer who has a piping problem to solve. The value of this book lies principally in the discussions of those practical considerations relating to the installation of piping and its allied equipment.

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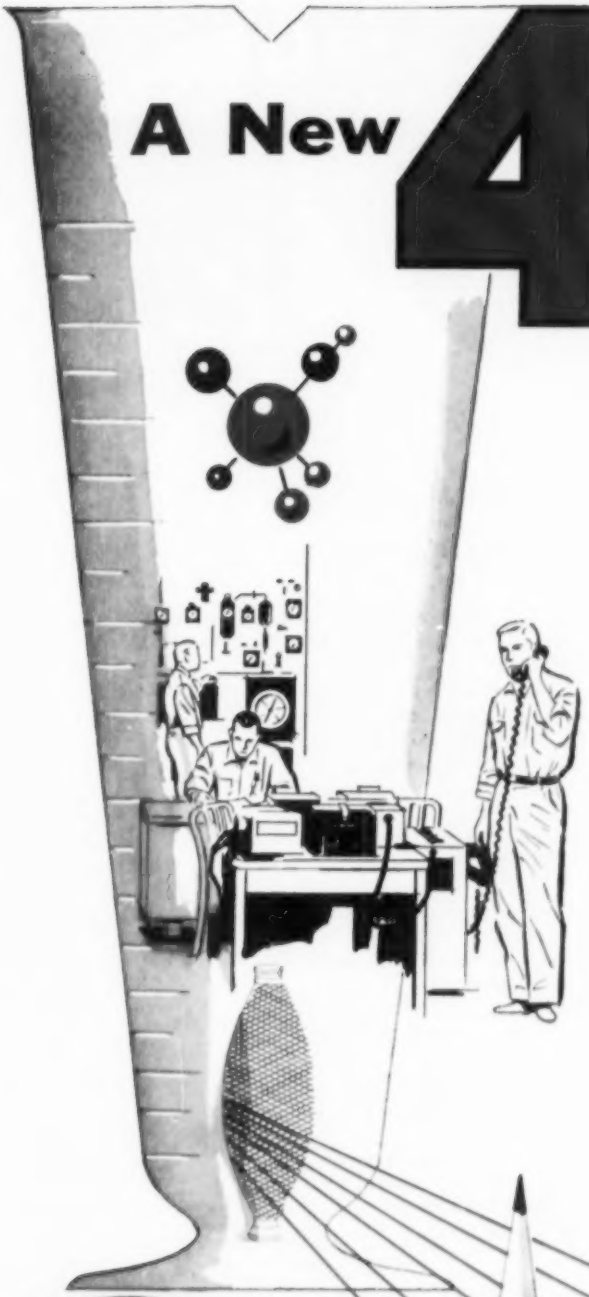

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Mr. Albert G. Blank
Sales Manager
Process Industries Sales

planning product drying with your research team

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U.S.I. CHEMICAL NEWS

March ★ A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries ★ 1957

Trimethyl and Triethyl Aluminum Piloted by U.S.I.

Trimethyl and triethyl aluminum, highly flammable liquids which ignite spontaneously in air, are now being produced by U.S.I. in pilot plant quantities. At present they are being tested as ignitors and fuels for ram jet and turbo jet engines, and also show possibilities as polymerization catalysts, and intermediates for chemical synthesis.

A sodium-based process is used to synthesize these two materials in the pilot plant, a process which can be used to produce them in commercial quantities as well. It is predicted that the commercial price will range between $2 and $5 per pound, although the price in pilot quantities is considerably higher.

Also available from the pilot unit is methyl aluminum sesquichloride, a mixture of methyl aluminum dichloride and dimethyl aluminum chloride. This product too may find use as a catalyst or chemical intermediate.

Alcohol and Chemical Sales Now Under Johnson

Warren E. Johnson has been named Manager of Alcohol and Chemical Sales for U.S.I. Mr. Johnson has been with the U.S.I. sales organization since 1940. He became Manager of the Boston Sales Division in 1944 and Manager of U.S.I. Chemical Sales in 1950. With this change, Mr. Johnson becomes responsible for industrial alcohol sales in addition to his previous product responsibilities. U.S.I. alcohol sales had formerly been under Alden R. Ludlow, Jr., who was recently named Director of Sales for the company.

Byck Appointed Manager of U.S.I. Heavy Chemical Sales

Lawrence C. Byck, Jr., has been named Manager of Heavy Chemical Sales for U.S.I. He has been assistant to the Manager of Chemical Sales during the past four years, and has been with the U.S.I. organization since 1945, in research and technical liaison positions as well.

In his new position, Mr. Byck will be responsible for sales of ammonia, nitric acid, and nitrogen solutions from the U.S.I. synthetic ammonia plant at Tuscola, Illinois. He will also be responsible for sulfuric acid sales from U.S.I.'s three plants at Tuscola, Illinois, Dubuque, Iowa and Sunflower, Kansas, and for sales of phosphoric acid from U.S.I.'s newly completed wet-process plant at Tuscola.

U.S.I. Phosphoric Acid Plant At Tuscola is Now Onstream

Plant is First in Country to Produce Wet-Process Acid Exclusively for Solid Fertilizer Industry

Thirty thousand tons per year of phosphoric acid (measured as P_2O_5) are now being produced at U.S.I.'s new Tuscola, Illinois plant. The bulk of the acid is expected to be used by solid fertilizer manufacturers in the Mid-west, making this the first wet-process phosphoric acid plant in the country to produce for non-captive consumption only. Availability of phosphoric acid in this area answers the need for a rich source of phosphorus, a need which has become evident with the trend toward high-analysis plant foods.

In the plant, insoluble phosphate rock is digested with spent sulfuric acid from the neighboring facilities of National Petro-Chemicals Corporation, a subsidiary of U.S.I. Calcium sulfate is filtered off and the resulting phosphoric acid is concentrated and marketed as a fertilizer raw material.

Section of U.S.I.'s new phosphoric acid plant.

With the completion of this plant, U.S.I. now makes ammonia, nitrogen solutions, sulfuric acid, and phosphoric acid at Tuscola. Because this area is the site of an integrated chemical center, the company feels that it can also manufacture other fertilizer raw materials if the demand becomes evident.

MORE

April 8-12 Set for 4th Chemical Progress Week

The Manufacturing Chemists Association (MCA), national sponsor of Chemical Progress Week, reports that industry support for the program is greater this year than ever before.

Chemical Progress Week was inaugurated in 1954 as a nationwide effort on the part of the Chemical Process Industries to acquaint the American public with the importance of chemistry and the chemical industry in daily life.

As has been the case in previous years, the working organization behind Chemical Progress Week is manned by volunteers from the industry. Last year some 1,500 participants were listed at National Headquarters and it is believed that approximately 7,500 additional people took an active part in implementing the program.

National Headquarters has prepared a wide range of materials and suggestions for participating companies to present to the public. Included are literature, displays, ads, radio and TV material, speeches, films, publicity releases and sample proclamations to be made by state governors.

Complete kits of ideas, samples and order forms can still be obtained from MCA, 1625 Eye Street, N.W., Washington 6, D. C.

New, Low-Cost Process for Separating Zirconium and Hafnium Acquired by U.S.I.

U.S.I. has taken an exclusive option on a new process for separating hafnium from zirconium chloride, developed by the Commonwealth Scientific and Industrial Research Organization of Australia. The separation is necessary where zirconium is to be used in atomic energy installations, since hafnium impurities destroy the excellent nuclear properties of zirconium.

Now in pilot plant stage at U.S.I.'s Cincinnati research laboratories, the process has been found to reduce considerably the cost of separating the two metals. It eliminates the series of cumbersome chemical extraction steps which other methods in current and projected operation employ.

U.S.I. is currently building a zirconium sponge plant in Ashtabula, Ohio, scheduled to come on-stream during the second quarter of 1957.

March ★ **U.S.I. CHEMICAL NEWS** ★ 1957

CONTINUED *Phosphoric*

Sodium Silicofluoride Produced

Sodium silicofluoride is manufactured as a by-product of the phosphoric acid process. This material is used in fluoridation of municipal water supplies and is also employed by the chemical process industries in the manufacture of enamel frits and laundry sours.

Giant filter is heart of phosphoric acid process at U.S.I.'s new Tuscola, Ill. plant.

New Cancer Studies Show Tumor Growth Reduced by Methionine and Cystine

Researchers investigating the biochemistry of cancer report that methionine and cystine, two sulfur amino acids, have been used to reduce the growth of sarcoma R-1 in experimental animals maintained on sulfur deficient semi-synthetic diets. These compounds also increased body weight as normal tissue, raised food efficiency, as well as increasing the difference in the ratio of normal tissue weight to weight of the tumor.

When guanidoacetic acid (glycocyamine) or glycine were used as further supplements, the addition of methionine overcame the toxicity of glycocyamine and brought about increased food efficiency and a favorable change in the ratio of body weight to tumor weight. The mixture of methionine and guanidoacetic acid was particularly effective in conserving body nitrogen under stress conditions such as the large sarcoma or toxic chemotherapeutic agents.

New Type Polyethylene Film Permits Packaging Liquids In Cardboard Containers

A new pinhole-free type of polyethylene film for liners has just been announced which will make it possible to ship liquid, semi-solid and anhydrous products in bags and boxes as well as drums and barrels. It is claimed that the new film gives positive protection against leakage.

The film is made by fusing together two simultaneous draws of polyethylene while the surfaces are still molten. Since it is almost impossible for pinholes or minute weaknesses to occur in exactly corresponding positions in each of two separate films, the result is a strong, moisture-proof material.

Pinhole-free polyethylene has great possibilities as a lining material for all types of shipping containers—to transport chemicals, dairy products and many other items.

This new container combines a pinhole-free polyethylene bag and a corrugated box. Containers of this type should be of interest for packaging liquid chemical specialties.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing the Editor, U.S.I. Chemical News.

New "blackboard" radiographic method is claimed to be fast and low-cost for industrial x-ray work. Advantages cited include: dry process, reusable plates, detailed images, and 20 to 45 seconds exposure-to-viewing time. **No. 1210**

Paint formulas are featured in new 46-page booklet on pigment extenders, flatting agents and filter aids. Presented on individual, 3-hole punched sheets are 24 formulas for solvent-thinned paints and 17 for water types. **No. 1211**

Imported crystal lattice models now distributed here have angles and dimensions based on data obtained by x-ray and electron diffraction. Linear scale is one Angstrom per 25 mm. Spheres have 20 mm diameter, are varied colors. **No. 1212**

Chemicals which can be piped through flexible polyethylene are charted in an 8-page bulletin on this type of piping. Also covered are properties of polyethylene pipe, sizes, estimated flow rates and installation procedures. **No. 1213**

New arsenosiloxanes are claimed to combine the water-repellent properties of conventional silicones with the fungicidal and pesticidal properties of arsenicals. Suggested for use as water-repellent insecticides. **No. 1214**

Chemically-modified fats known as acetoglycerides have been prepared and patented by the USDA. Some are flexible, wax-like, non-greasy in feel — show promise in foods, plasticizers, cosmetics, lubricants. Process can be licensed without cost. **No. 1215**

New one HP homogenizer said to do jobs usually entrusted to 3 to 5 HP models is now on the market. Designed to process about 1000 lbs. per hour of semi-pastes or other viscous materials up to 30,000 cps, at 3600 rpm. **No. 1216**

An index of all isotopes available commercially, and their sources, can be purchased as a 64-page book listing over 2000 items. Included are stable and radioactive isotopes and hundreds of isotope-labeled compounds. **No. 1217**

1,1,1-Trichloroethane in reagent grade is now available as high-safety chlorinated solvent for the laboratory. Suggested as substitute for chloroform or carbon tetrachloride in dithizone tests for metals because of low toxicity. **No. 1218**

o-Nitrophenyl-beta-D-galactoside of especially high purity can now be obtained which permits a dependable, simple assay of the activity of galactosidase used in studies of protein synthesis. **No. 1219**

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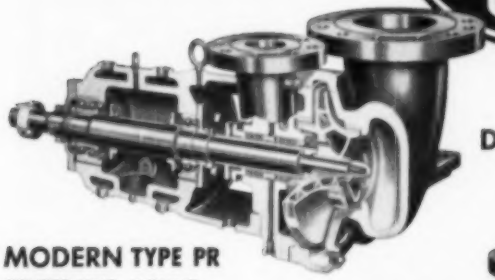

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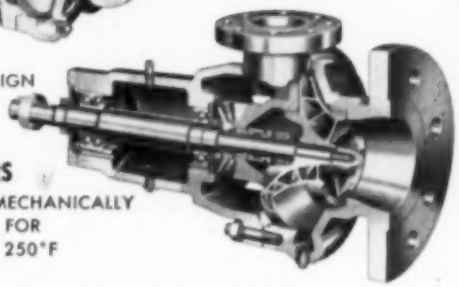

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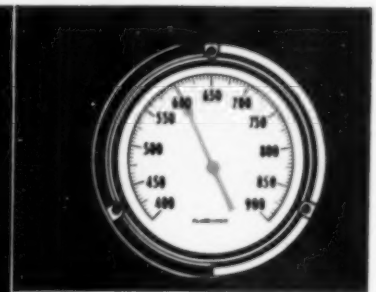

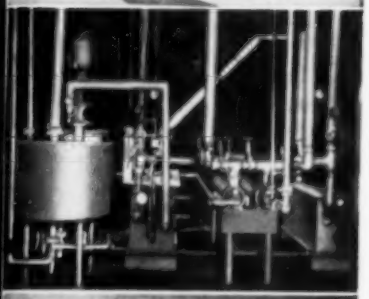

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The other day a bank officer, who has followed the chemical industry most of his life, remarked, "It has just occurred to me that the chemical industry is coming to the end of one era and embarking on a new one." What he meant was that leaders in chemicals are currently engaged in a good deal of soul searching and crystal gazing in trying to evaluate their current situation and the outlook for the next five to ten years.

Obviously the chemical industry is not an infant industry any more. In point of sales it is the fifth largest industry in the country. Its growth, even in the last decade, has been more phenomenal than that of any industry except automobiles. Without impugning the judgement of the top brass in the industry, until the last year or so their viewpoint has been the viewpoint of people running a new industry, an industry that was expanding faster than managements could keep pace.

The chemical industry has never had the problems that have beset other industries in the past—problems of financing, of excess inventories, of a devasting industry depression, of serious overproduction, or even, until lately, troublesome labor problems. Its chief problem was to build enough plants to increase production fast enough.

Time to Take Stock?

Now, however, there are signs that the industry is reaching, shall we say, 'middle age,' and middle age is a time for taking stock and wondering a bit soberly about the future. It is not a time for slowing down or for disillusion. Individuals make their greatest progress usually in the period of middle age.

Chemical officials appear to be as optimistic as ever about their industry's future. Forecasts for five years ahead envision large sales increases. Preparations are being made for this by a continuing program of plant building which will be larger this year than last, and quite probably larger in 1958 than in 1957.

One reason for the building program is to keep one jump ahead of higher plant costs, higher steel costs, and higher labor costs, which are of course the basic causes of all rising costs. In other words, it is a race to keep ahead of inflation. Inflation from one viewpoint would be all very well if it simply made real estate and fixed assets more valuable. Anyone with investments in real estate or securities theoretically just needs to hold on to prosper. But actually it does not work out that way. There are penalties and pitfalls in what sometimes seems a one way boulevard.

These penalties are giving farsighted chemical management food for thought. They look, for example, at their records in sales and earnings for the past five years, during which the industry has spent billions on new plants. They see that sales are up to new high levels but that profits have not kept pace. In some cases last year, profits were below those of 1955, in spite of larger sales and larger outputs.

The major factors in profits are now labor costs and rising costs of materials and freight. These higher costs of course apply to new plants. There used to be a time when a dollar put into plant could be counted on to produce a dollar of sales. Now, especially in some older heavy chemicals, it would probably require two dollars or more of plant to produce a dollar in sales volume. With taxes as they are, some chemical companies feel that they cannot afford to make this sort of investment—especially in competitive fields.

And Integrate on Both Ends?

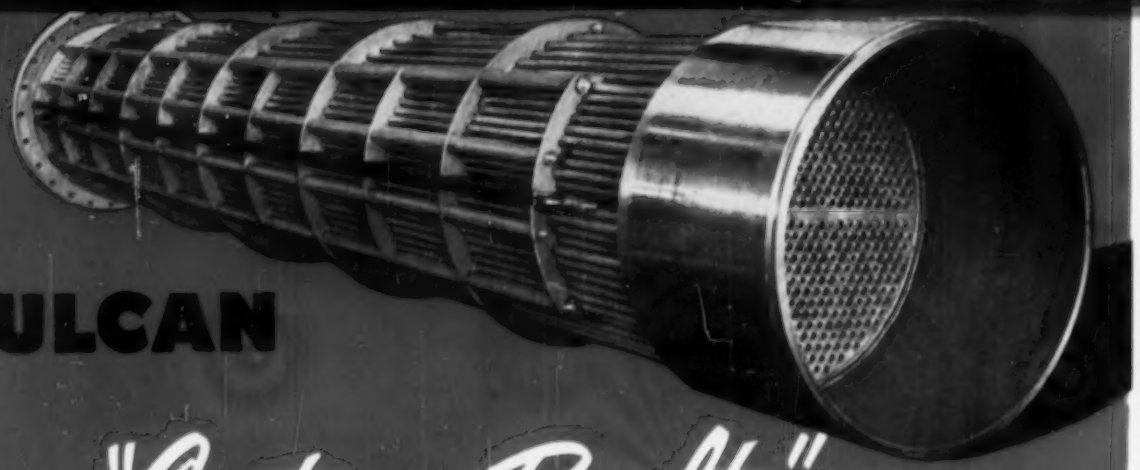
One matter that chemical executives are therefore giving increasing thought to is how to "trade up"—how to increase profit margins. One way to do this, a way already adopted by some firms in the industry, is "integration" by means of acquiring sources of raw materials, and on the other end by moving closer to the consumer field. This is done by carrying chemicals one step further—making, for example, synthetic fibers, instead of just the chemical raw materials for the fibers.

Both Monsanto and Dow have acquired substantial oil and gas reserves to protect themselves against the apparent slow rise in oil and gas prices. Union Carbide, although a major producer of petroleum chemicals, has not acquired oil reserves but is taking a look at coal as a possible long range raw material.

The trend toward moving closer to the consumer will probably be accelerated over the next few years as a means of widening profit margins. Du Pont has long been deeply in consumer goods with paints, rayon, and synthetic fibers. Union Carbide, with its Prestone anti-freeze and flashlight batteries, has also been in consumer goods. More recently, Carbide acquired the Visking Corp., maker of vinyl film.

Monsanto is well into synthetic fibers and in the consumer field also makes "All," the synthetic detergent which incidentally made a little fur fly in the soap industry. Dow makes Saran wrap, familiar on every chain store counter.

Going more widely into consumer goods fields of course brings the danger that chemical firms will be competing with their own customers. But it should be noted that more and more firms in consumer goods fields have been getting into chemical production. The chemical industry may have to fight this by more ventures into consumer goods.



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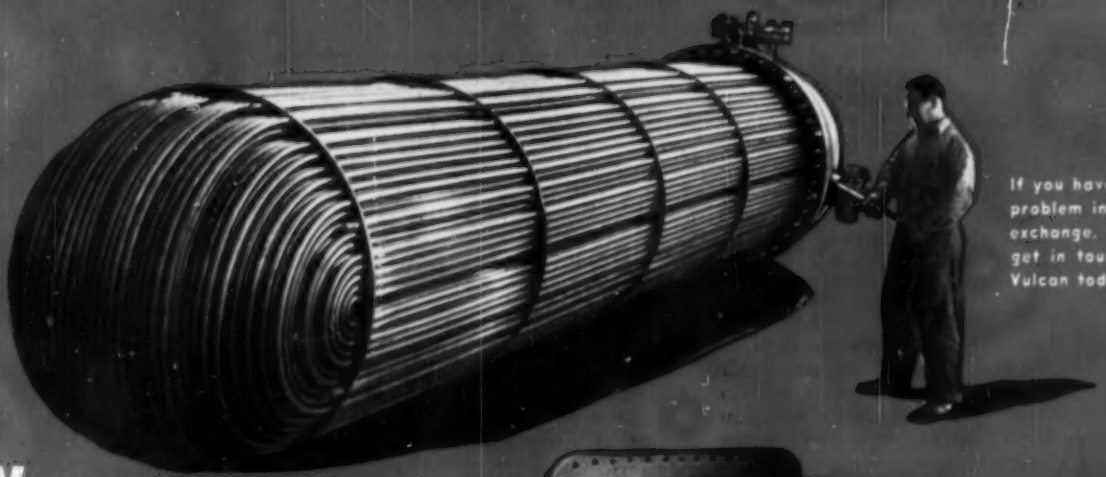

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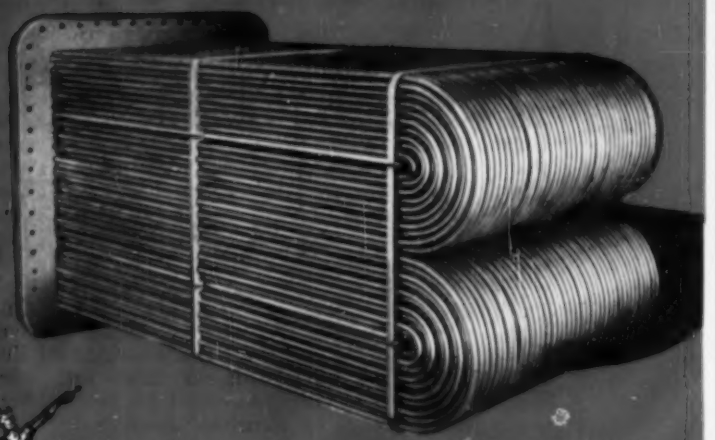

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CEP

opinion and comment

CPW—AID TO PUBLIC UNDERSTANDING

The way the engineer sees himself *versus* the way he is seen by the public is commented on in two sections of this issue of *CEP*. "Doc" Lewis' brilliant essay (page 19) and the two views on why the profession isn't getting the recognition it wants (page 8) should be thought-provoking.

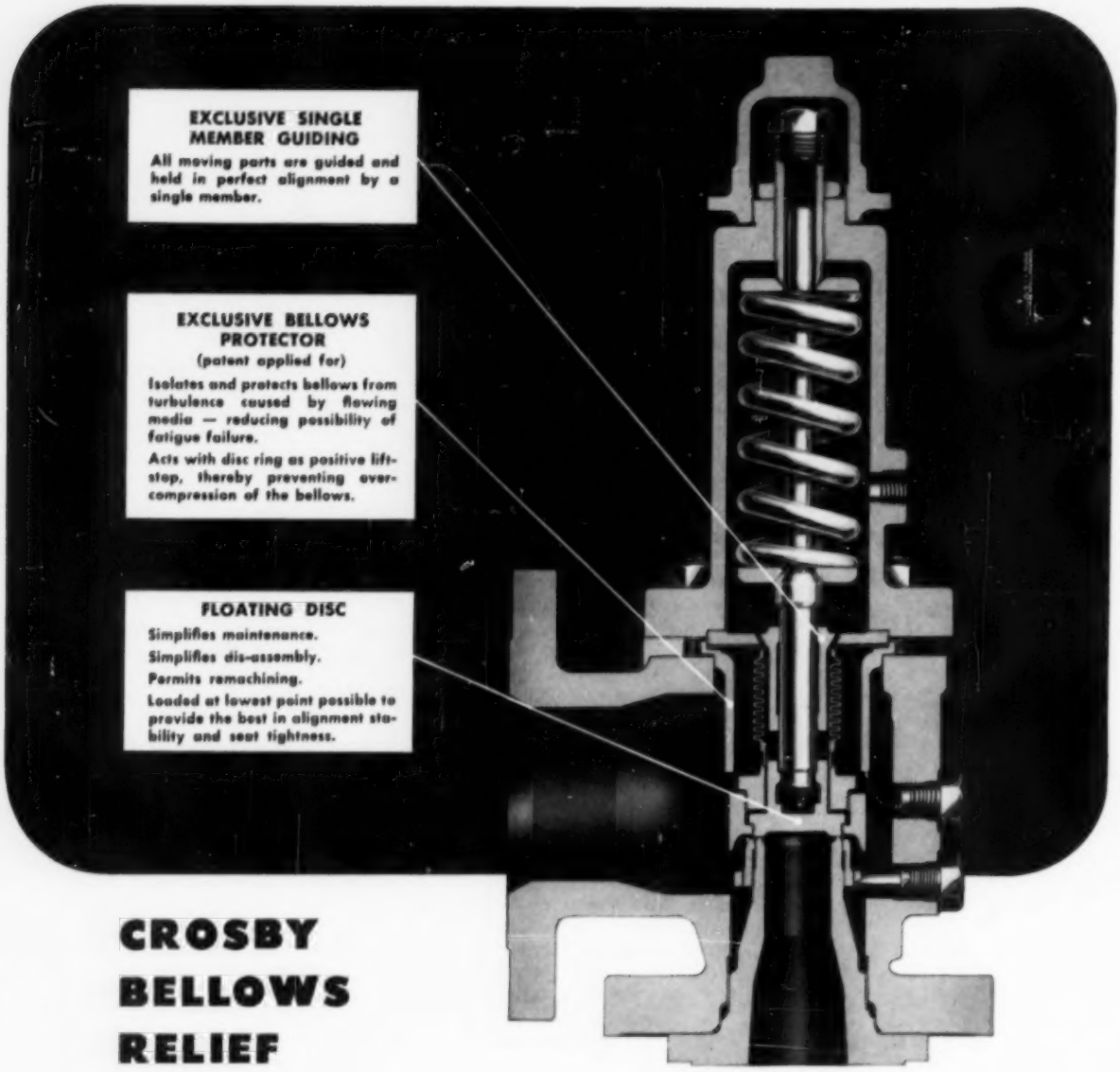
Further, we would like to nominate for consideration an engineer-public relationship factor not mentioned in the above-cited articles. This has to do with the apparent lack of confidence placed in the public by those who decide what is to be popularly read and heard about the experiments and other events which lead to conversion of states of matter into forms which ultimately end in consumer benefit. In practice, the reluctance to tackle this kind of subject material acts as a buffer between much of what the chemical engineer does and what the public comes to learn about what he does.

A movement that got underway three years ago, and is about to be repeated shortly, represents a kind of activity which may very well bring about improvement in this situation. This movement is *Chemical Progress Week*, which will have its fourth celebration April 8-12. CPW is sponsored by the Manufacturing Chemists' Association and is carried on in various locales by member chemical companies, who specifically assign or otherwise encourage personnel to act somewhat as a task force during this week. Well-organized, its activities range from being host to employee-family, educational, press, and other groups, to the dissemination of source materials for use in schools, homes, and by the popular communications media. In addition, speakers are made available.

The purpose of all this is to attract the public's attention to, and inform them about, the chemical industry—in a dignified manner, without ostentation. The sponsors hope to stimulate real interest in the chemical industry on the part of the public—what it does, what it has accomplished, and how it is essential to the American way of life—and then to satisfy whatever interest is so generated with skillfully prepared information. The inspiration of young people toward careers in science and engineering is also an important goal, which is handled both directly and indirectly, through a related effort involving science teachers. The science teachers of the secondary and primary schools are provided with information regarding scientific activities of the industrial community, are brought into contact with local scientists and engineers, and their interest and prestige is increased in other ways as well.

CPW, in addition to seeking its primary goals, may become an important aid to the chemical engineering profession in helping the profession to become better known as a servant of vital public interests. There are several aspects of CPW's operation at the local level which may prove convincing to those who, once persuaded, can do much to get our story across to the public.

—JBM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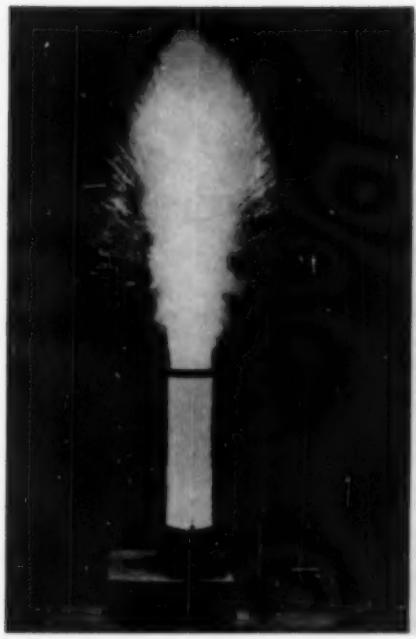

Result of laboratory test involving explosive properties of titanium powder—300 mg. in lucite tube.

recent findings on DUST EXPLOSIONS

Irving Hartmann * | U. S. Bureau of Mines, Pittsburgh, Pennsylvania

The economic importance of industrial dust explosions has long been recognized. To combat this hazard, the National Fire Protection Association through technical committees has prepared a series of safety codes containing recommendations for the safe design and operation of plants in various dust-producing industries. These codes have been adopted as standards of the American Standards Association and serve as a basis for legislation by several states.

The Bureau of Mines, United States Department of the Interior, has long been interested and actively engaged in studying dust explosions. The work is centered at the Bureau's Central Experiment Station, Pittsburgh. At a unique experimental coal mine and in laboratories intensive research on coal dust and gas explosions in mines has been underway since 1911. With this background and experience it was natural that the Bureau would be called on to undertake research on the related problems of industrial dust explosions. The first important study resulted from a serious explosion of pulverized coal-tar pitch (*3*) in New York. Then followed systematic investigations of military smoke and pyrotechnic mixtures, metal powders, plastics, agricultural dusts, drugs, dyes, insecticides, miscellaneous chemical compounds, and coal dusts from a wide range of coal seams. The Bureau's present investigations of dust explosions can be grouped into three phases, namely:

1. Laboratory evaluation of the explosive characteristics of all types of combustible dusts and powders, and studies conducted on various parameters that affect explosibility. Special studies have been made on the effect of admixtures of inert dusts with the combustible; effect of particle size; effect of moisture; effect of elevated initial pressure; effect of oxygen-enriched atmospheres; and effect of nature of ignition source on explosibility.

2. Basic research on the mechanism of ignition of dust particles and the propagation of combustion waves through dust clouds. Use is made of stationary laminar and turbulent dust-air flames of the Bunsen type, and those with flat-flame fronts. Normal burning velocities of flames are measured as functions of dust concentration, oxygen partial pressure, and particle size; and the effects of radiation, turbulence, and oxygen diffusion are investigated with the aim of achieving a theoretical understanding of dust flames and explosions.

3. Investigations in partly open chambers or galleries, ranging in volume from 1 to 216 cu.ft., and in ducts on explosion venting, flame speeds, flame quenching, and related problems.

The information accumulated in the wide range of projects has extended knowledge of the causes and development of dust explosions and of preventive measures against them. Data have been used by design and operating engineers of plants, by insurance men, and by Government inspectors; they have formed a basis in the preparation of safety codes for various industries. Results of many studies have been described in Bureau publications, in technical journals (*4, 5, 6*), and in special reports furnished to manufacturers. Additional information from recent and current projects has yet to be released. This paper proposes to discuss briefly a few recent studies.

Effect of Moisture on Explosibility of Dusts

In general, the presence of moisture and to some extent even high atmospheric humidity has palliative effects on the explosibility of many dusts. This is due to several causes. Since moisture has an inhibiting and cooling effect because energy is needed to heat and vaporize it, the energy available for ignition of the dust cloud is reduced. The water vapor acts as an inert gas, diluting the atmosphere and reducing the percentage of oxygen in it. A film of moisture on nonconducting surfaces of the explosion space promotes leakage of static electricity to ground; thus the hazard of ignition by static discharge sparks is reduced. The most important effect of moisture is frequently its ability to wet and agglomerate the fine particles of combustible dusts, thereby reducing their dispersibility. These apparent and real beneficial effects of moisture vary with the nature and particle-size distribution of dust, with the percentage

* I. Hartmann is a physicist and chief of the Branch of Dust Explosions, Division of Explosives Technology.

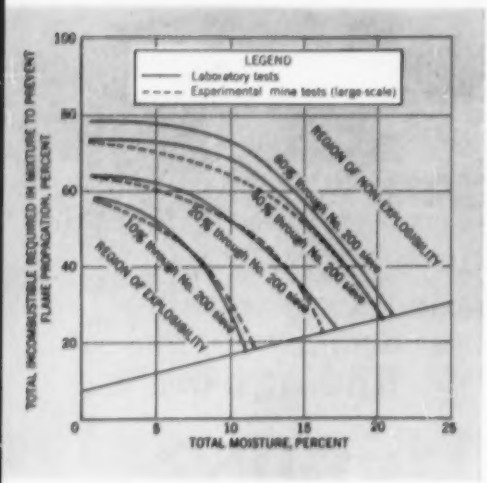

Fig. 1. Effect of moisture on flammability of mixtures of high-volatile, bituminous Pittsburgh coal dust and limestone dust.

of moisture and its bonding to the dust, and with special conditions in the surrounding vessel or space.

Reaction of moisture with magnesium, aluminum, and some other metal powders produces hydrogen gas, particularly at elevated temperatures. This may reduce the protective oxide coating on the surface of dust particles and make them highly sensitive to ignition. In some dusts a small amount of moisture promotes fermentation or other microbiological action leading to heating and occasionally to fires. Other heat-producing processes are chemical reactions between certain dusts and moisture and galvanic cell effects due to the presence of moisture.

To confirm limited large-scale mine tests, laboratory experiments were conducted recently on the effects of moisture on the explosibility of coal dusts of various ranks and particle sizes. The tests were made by determining the proportion of inert (limestone) dust required in a mixture with the coal dust to prevent ignition and flame propagation when dispersed through a laboratory furnace heated to a preset standard temperature. The work has an important bearing on coal mine safety. The data indicate how much limestone dust is needed to prevent propagation of explosions of coal dusts containing various amounts of moisture. The test data for coal dusts prepared from the bituminous Pittsburgh seam are shown in Figure 1. Since the inherent moisture content of this coal is low (2 to 3%), in the experiments additional water was added to, and mixed with, the dust. The abscissa represents the total moisture and the ordinate the total incombustible (ash, moisture plus added limestone) in the mixtures; the latter is frequently designated as the "relative flammability" of the coal dust.

As can be seen from Figure 1, increase in moisture content up to about 5% has little effect on the relative flammability, but further increase in moisture results in pronounced reduction in flammability of the coal dust. The effect of moisture is greater for coarse coal dust than for more finely divided dusts. The inhibiting or inerting effect of moisture is considerably greater, especially for the coarser dusts, than the effect of the solid incombustible (chiefly added limestone) in the dust mixture. As an example, the dust of "20% through No. 200-sieve fineness," which is typical of dust present on the floor of many mine entries, failed to propagate an explosion when its moisture content was about 17% and its total incombustible content (moisture plus ash) about 22%. In comparison, when the dust was dry it required an incombustible content of about 65% (ash plus limestone) to prevent propagation of an explosion; in other words, in this instance the moisture was more than three times as effective as the limestone.

Flame Velocities in Dust Explosions

Knowledge of flame velocities, or rates of propagation of the flame front relative to the fixed surroundings is important for understanding the explosion process as well as for planning and designing quenching, diverting, and other protective measures. In coal dust explosions in a 1,300-ft. entry of the experimental coal mine, flame velocities were measured in several hundred tests. The velocities of most self-sustained explosions range from about 200 to 2,000 ft./sec. In a few tests velocities that exceeded 6,000 ft./sec. were recorded.

A number of explosion tests were made with aluminum and magnesium in the outermost 50-ft. section of the mine entry near the open pit mouth. The flame velocities at 20 to 30 ft. from the origin of the explosion ranged from about 800 to 3,500 ft./sec.

In a recent study of factors that govern flame propagation, explosions of cork, cornstarch, cellulose acetate, sugar, coal dust, and wood flour were set off in a 1-cu.ft. gallery to which circular, square, and rectangular horizontal ducts of 2 to 17 ft. in length were attached. In a few tests, explosions were initiated in a 64-cu.ft. gallery, to which a square (18- by 18-in.), 32¼-ft. duct was connected. The flame velocity in the ducts was measured independently by photoelectric cells, by ionization probes, and by a direct photographic method. The ionization probes and cameras were used simultaneously in several sets of experiments. The flame velocities measured by the two methods agreed within 5% or less in nearly all tests. Data obtained with the photocell method were generally in fair agreement with results by the two other methods.

The experiments showed that within the range investigated the average flame velocity in dust explosions initiated in a closed gallery increased, though not linearly, with increasing length of duct. The flame velocities within a duct increased approximately linearly with distance from the gallery toward the open end of the duct. [See Figure 2(a).]

Table 1.—Average and Terminal Flame Velocities

Dust	Dust concentration in gallery, oz./cu.ft.	Flame velocity in duct, ft./sec. Avg.	Terminal
Cork	0.40	800	1,200
Cork	0.50	770	1,150
Cornstarch	0.40	730	1,220
Cellulose acetate	0.50	630	940
Sugar	0.60	530	810
Coal	0.60	500	890
Wood flour	0.50	400	610

Table 2.—Reduction in Flame Velocity

Vent opening in gallery, sq.in.	Flame velocity in duct, ft./sec. Avg.	Terminal
0	630	940
5.0	490	730
8.6	370	500
11.5	260	200

Table 3.—Flame Velocities

Distance of secondary vent from gallery, ft.	Flame velocity in duct, ft./sec. Avg.	Terminal
2.5	260	320
5.5	300	380
11.5	630	830
No secondary vent	660	940

Table 1 lists the average and terminal flame velocities in an 11-ft. long, 4¼-in. diam. circular duct attached to the 1-cu. ft. gallery for explosions of several dusts of through No. 200-sieve fineness.

The effect of dust concentration on the average flame velocity in explosions of cork is shown in Figure 2(b). The maximum velocity for this and other dusts was recorded in explosions of dust clouds above the stoichiometric concentrations.

As might be expected, higher flame velocities were obtained in explosions of fine dust than in those of coarse dust. [See Figure 2(c).]

An 83% increase in the cross-sectional area of circular ducts (5¾- vs. 4¼-in. diam.) resulted in a reduction in the average flame velocity in cellulose acetate explosions from 630 to 490 ft./sec. in 11-ft. ducts and from 660 to 570 ft./sec. in 16-ft. ducts. The flame velocity was somewhat higher (50 to 80 ft./sec.) in circular ducts than in square or rectangular ducts of equal cross-sectional areas.

Table 2 shows the reduction in flame velocity in cellulose acetate dust (0.50 oz./cu.ft. concentration) explosions propagating through the 11-ft. long 4¼-in. diam. circular duct, when successively larger vents were provided in one wall of the 1-cu.ft. gallery in which the explosions were initiated.

It can be noted that in the last test the terminal velocity at the end of the 11-ft. duct was smaller than the average velocity at midpoint of the duct. In ducts of much greater length this might be true in most instances because, unless fresh fuel and sufficient oxygen are provided along the duct, the flame is cooled and must gradually die out within long ducts.

Another series of experiments with cellulose acetate was made with a 16-ft., 4¼-in., circular duct, in which an unrestricted vent (equal in area to the cross-section of the duct) was provided at various distances from the 1-cu. ft. gallery. The flame velocities measured in these tests are shown in Table 3. Data indicate that provision of the secondary vent reduced the flame velocity in inverse proportion to the distance of the vent from the gallery.

Explosion Venting Under Special Conditions

One of the most effective measures for reducing damage from dust explosions is to provide properly designed and proportioned and suitably placed explosion-relief vents in the equipment or structure within which an explosion might occur. Generally, the most effective vents are free or unrestricted openings. However, in practice it is frequently necessary to provide some type of closure for such openings, like diaphragms that tear or blow out under low pressure, hinged or blow-out panels, louvers, scored glass panes, hinged windows, or light sections in wall or roof surfaces. The problem of venting has been investigated by the Bureau of Mines for several years. Data on venting requirements for relatively weak explosions of numerous dusts (*7*), on the effectiveness of various diaphragms (*8*), and on venting into adjoining large chambers of finite volumes (*1*) have been published. Recently a guide for explosion venting was published by the National Fire Protection Association (*2*). This guide outlines general principles and contains certain recommendations relating to the design and utilization of explosion vents. Recommended (unrestricted) venting areas range from 1 sq. ft. for each 10 to 30 cu.ft. of enclosure for small equipment and light construction, to 1 sq.ft./80 cu.ft. for large rooms and buildings with heavy, reinforced concrete construction. Experimental data on venting requirements for strong dust explosions and on venting through ducts will be published in the near future. In this paper there is given only a brief discussion of a recent development on the simultaneous release of explosion pressure and flame quenching in vents.

Wire-Screen Device

In many old plants and in improperly designed new plants equipment in which explosions might occur is located so far from an outside wall or roof that it is not possible to release the explosion products to the outer atmosphere, but the dust, gases, and flame are permitted to issue into the plant area. This practice is dangerous and has resulted in accidents.

Preliminary laboratory research on this problem was conducted at the Bureau of Mines in 1942 in an effort to quench or trap dust-explosion flames by wire screens. The study was resumed recently with the idea of providing pressure relief but preventing issuance of flame from the explosion chamber through the vent or through ducts attached to the vent; the process might be termed "quench-venting." The experiments were carried on in the 64-cu.ft. gallery with dust clouds of cellulose acetate, atomized alum-

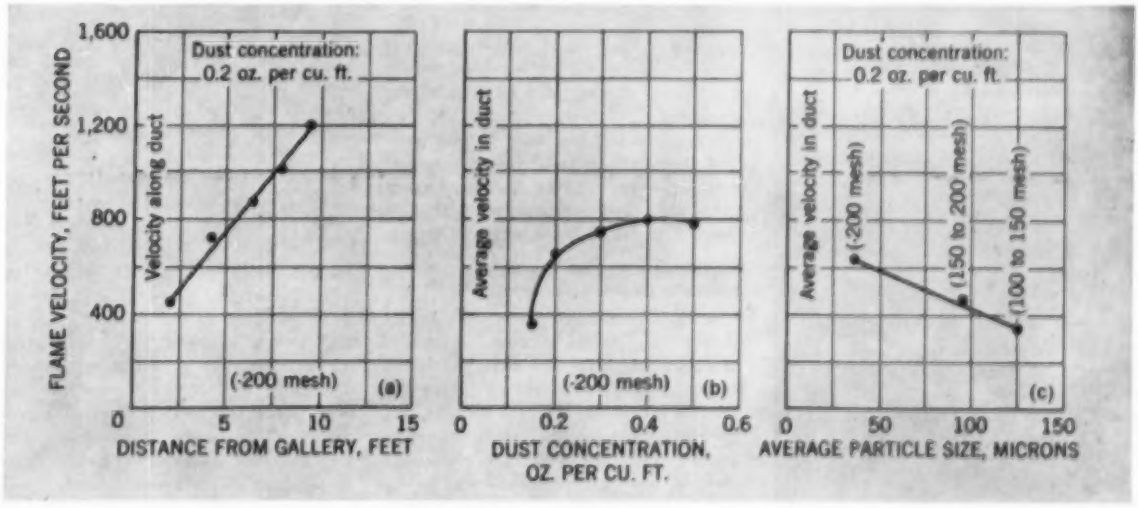

Fig. 2. Flame velocities of cork dust explosions in 11-ft., 4.25-in. I.D. duct attached to 1-cu.ft. gallery.

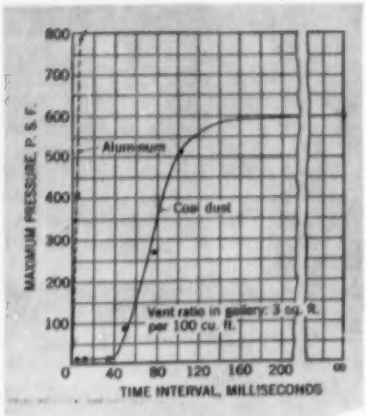

Fig. 4. Effect of time interval between initiation of explosion and water dispersion on pressures in 216-cu.ft. gallery.

inum, corn starch, soybean, coal, cork, grain, and wood flour. Due to strength limitations of the gallery the tests were generally not made at the optimum dust concentrations. In the tests an 18- by 18-in. (or 15- by 15-in.) vent was provided in one or in two adjacent vertical sides of the cubical gallery. In some tests both vents were free or unrestricted; in others one vent (or part of a vent) was free, and in the other a wire-screen arrangement was inserted; or wire screens were provided for both vents.

Numerous trials were made with various screen arrangements. One satisfactory combination with which most of the explosion tests were made consists of three nests of screens, spaced 6 to 7 in. apart. Each nest contains three sets of two screens, one a steel-wire screen and one a bronze screen, with ⅛-in. spacers between the sets. The steel screens are of welded construction, 6- by 6-mesh/in., 0.054-in. wire diam. The bronze screens are 14- by 18-mesh/in., with an 0.011-in. wire diam. Among other effective screen arrangements was one consisting of nine sets of two screens —one steel and one bronze, spaced ½ in., 1 in., or 2 in. apart. The fine-mesh bronze screens had the greatest effect in cooling and otherwise quenching the explosion flames.

The purpose of the heavier steel screens was to prevent destruction of the screen device in each test and to assure proper screen spacing. A heavy screen should be used on the outer side of the device in all plant installations, in order to prevent ejection of sharp screen fragments and possible injury to near-by personnel. To protect the screen devices from contamination by dust, fumes, or fibers from the explosion space or from the plant area, the first and last screens in the device should be covered with a thin metal foil or paper diaphragm.

With the three-nest screen arrangement explosion flames of all eight dusts mentioned were quenched.

Figure 3 shows the effectiveness of the screens in a coal dust explosion; the screen arrangement was used in the right vent and as can be seen, coal dust (burned and unburned) is issuing through it, but no flame. On the front vent no screens were used, and flame is seen projecting from the gallery.

With cellulose acetate explosions, experiments were made with screens installed in fixed positions at various distances from the gallery in ducts attached to one vent. In some tests at the junction of the gallery and the duct a weak diaphragm or a hinged, light panel was installed that opened under light pressure. The flames were quenched within the duct in all tests.

In all tests in which the vent or duct contained protective screens the explosion pressures within the gallery were higher than in similar explosions in which the vents were unobstructed and flame issued from the gallery. The pressure increase results from the reduction in vent area by the screens.

The results of the study to date indicate that it is possible by the aid of screen devices to arrest flames of many industrial dust explosions within a short distance of their point of origin.

Fig. 5. View of polyethylene bags in duct for arresting dust explosions (air vane pressure pickup in foreground).

Quenching Incipient Explosions, Preventing Secondary Explosions

A dust explosion during its initial phases is relatively slow. Time is needed to disperse the dust, mix it in proper proportion with air, drive off part or all of the volatile constituents (if any) from the dust, or in some instances melt and volatilize the outer part of the dust particles, and bring about actual ignition—there is always an ignition lag period. The volume of dust involved at the start is likely to be small, and the pressure at the start of a dust explosion rises slowly. It is therefore highly advantageous to achieve control of an explosion during the incipient stage.

The problem was studied with coal dust and with atomized aluminum explosions in the 64- and 216-cu.ft. galleries. It was found that pressures in these explosions could be successfully limited to small values by dispersing quenching agents from four to eight polyethylene bags or other containers suspended in the galleries. In the tests with aluminum only water was used; coal dust explosions were controlled with water, limestone, and salt. The time of dispersion of the quenching medium relative to the initiation of the explosion was critical; dispersion was accomplished in some tests manually by presetting a timing switch, and in other tests pressure-sensitive, bellows-type pickups were triggered by the explosion itself. Coal dust explosions were quenched successfully when the time interval between ignition and dispersion of the quenching agent was 5 to 35 msec.; partial control was achieved up to about 80 msec. In the aluminum explosions complete control resulted only when water was dispersed simultaneously with the aluminum, which is obviously impossible in an actual explosion. Partial control resulted in several tests when the time interval was 5 msec. The effect of the time delay on explosion pressures is shown for a number of aluminum and coal dust explosions in Figure 4.

In many industrial explosions and in coal mine explosions the initial ignition is usually limited to a relatively small amount of combustible in a small volume. However, frequently the disturbance created by this explosion disperses dormant dust off the adjacent mine or plant surfaces, particularly the elevated surfaces; this provides fresh fuel to the flame and causes it to spread, and sometimes results in a second or even more explosions, some at remote locations.

To study measures for preventing the development of secondary explosions a wide variety of experiments were performed in the 64-cu.ft. gallery, to which a 32¼-ft. duct (18- by 18-in.) was connected, which led into a 216-cu.ft. gallery. The explosions were initiated in the 64-cu.ft. gallery, and unless checked they propagated through the duct to the larger gallery, dispersing and igniting dust that had been placed on a shelf therein before the test. In some experiments dust was also distributed on the duct floor. Explosions of cellulose acetate, coal, cornstarch, wood flour, and atomized aluminum were studied.

Some secondary explosions were prevented by providing one or more vents in the duct between the galleries. Other explosions were stopped by dispersing water, limestone, or salt from polyethylene bags or other containers suspended in the duct; by dispersing the quenching agents from V-shaped troughs installed in the duct; and by installing one or two water sprays in the duct.

A number of secondary coal dust explosions in the 216-cu.ft. gallery were prevented by diverting the flame of the primary explosions through 18-by 18-in. vents in the connecting duct. This was accomplished most effectively when the vent was located within 13 ft. or less of the initial explosion, that is, from the 64-cu.ft. gallery. It was not possible to prevent secondary explosions of atomized aluminum by this procedure.

Secondary explosions of all the dusts mentioned above were successfully prevented by dispersing water, limestone, or rock salt from polyethylene bags suspended from the top of the duct, placed 3 ft. apart along the center line. Aluminum-dust explosions were controlled only with water. When water was used (generally 1 qt./bag) a minimum of four to six bags was required. With limestone dust (1.7 lb./bag) six bags were needed; and with rock salt (0.7 lb./bag) six bags were needed. The quenching agent was generally dispersed by firing detonators within the bags. The firing circuit was actuated either by a preset timing switch or by an air motion vane or a bellows-type pressure pickup acted on by the pressure wave preceding the flame through the duct; the pickups were mounted in the duct about 18 in. from the 64-cu.ft. gallery. For successful explosion control the distance between the pickup station and the containers with quenching agents must not be too short, to assure that the flame has not reached and possibly passed beyond the quenching agent before its dispersion. In long ducts it would be advisable to provide several sets of quenching barriers of this nature. Figure 5 is an internal view of the duct, showing several polyethylene bags of water, with the air motion vane in the foreground. In some experiments dispersion of water from the polyethylene bags and quenching of the explosions was accomplished without detonators, due to bursting of the bags by the pressure wave.

Secondary explosions of the dusts were successfully prevented by discharging of water or limestone dust from several V-shaped troughs mounted across the duct near the top. The capacity of each trough was 1½ qt. of water or 3 lb. of limestone dust. For tests with water, a sheet metal lid was attached over the trough with a ½-in. longitudinal opening along each side to control discharge of the water. The troughs were held in upright position by thin wires attached to the top of the duct. When a pressure wave from the explosion reached the troughs, it caused them to tip, breaking the wires and permitting discharge of the quenching agent.

Secondary explosions of all the dusts tested were prevented by discharging one, or in some instances two, water sprays in the path of the explosion within the duct. The operation of the sprays was controlled either by a preset switch arrangement or by the pressure pickups mentioned before; in the latter instance the distance between the pickup and the spray nozzles had to be sufficient to permit operation of relays and a quick-acting magnetic valve near the nozzles before the flame reached the spray position. Water was supplied by a 210-gal. surge tank, maintained under 85 lb./sq.in. compressed air pressure. Explosions could not be prevented with the ½-in. spray nozzles fed directly from a water line. In some tests the nozzles were placed at the center line of the duct with the sprays directed toward the oncoming explosion. In other tests the nozzles were set at the top of the duct with the sprays directed downward across the duct.

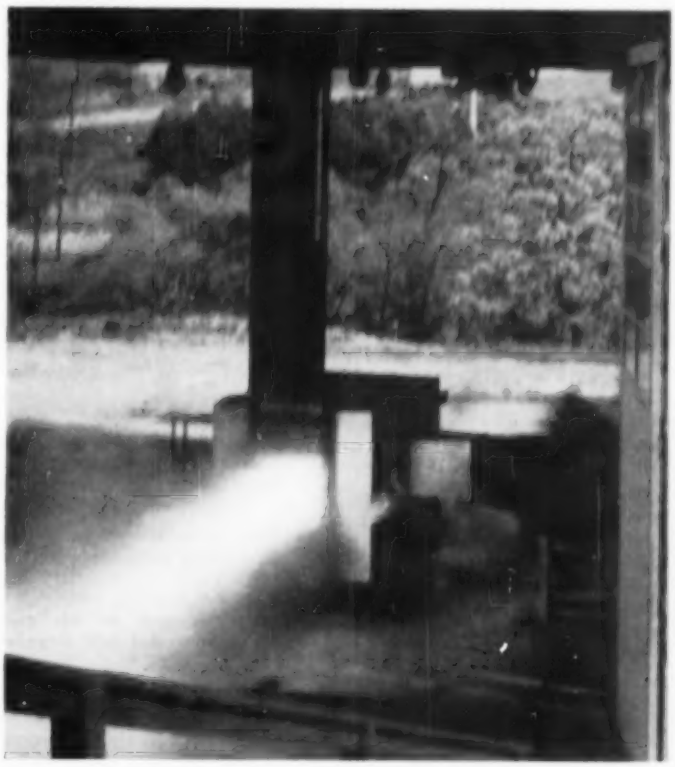

Fig. 3. Coal dust explosion released from 64-cu.ft. gallery through an unrestricted vent and through a screen-protected vent.

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The role of air contaminants in formulating OXYGEN PLANT SAFETY PRINCIPLES

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Safe operation of air separation equipment is a subject of growing importance because of the vastly increased rates of tonnage oxygen and nitrogen usage by the chemical and metallurgical industries. Much of the large new demand is at locations under heavy and increasing air pollution —conditions requiring fullest application of present technology. Reduction of hazards requires understanding. To this end, past published data provides limited knowledge.

Original data developed at Air Products by controlled explosion tests and solubility studies upon combustible contaminants permit the formulation of new safety principles consistent with historical findings.

The prevention of combustible contaminants (i.e. fuel) accumulation is the first line of defense against hazards. Various fuels have widely different safe limits, and all must be considered jointly for an effective safeguard.

Monitoring air before plant construction aids safe design and plant layout. Continuous monitoring during plant operation is a requirement for safe operation in heavily polluted areas. A new tool—the continuous hydrocarbon analyzer—provides a fresh dimension to the monitoring problem.

This article presents new information on the character of materials and explosions in oxygen plants, and is not intended as a review of design and operating practice.

The accompanying historical review illustrates that the published literature has been mainly concerned with the role of acetylene in the air plant mishaps. Acetylene has been regarded as especially significant for several good reasons. Large numbers of air separation units have been closely associated with acetylene production units; acetylene has a *very* low solubility, is highly reactive chemically (forms ozonides and is oxidized more readily than most other hydrocarbons) and acetylene can be exploded even in the absence of oxygen.

Through the last several decades, these particular characteristics of acetylene have resulted in the adoption of design and operating practices which must have protected many air separating plants from other hazards also. The use of adsorption and purge techniques suitable for avoidance of the acetylene hazard would also simultaneously remove other potentially hazardous contaminants, if present in low concentrations. Historically, acetylene has been responsible in many cases; the possibility of solid acetylene-liquid oxygen explosions has been experimentally established, the accumulation of acetylene in oxygen plant reboilers has been demonstrated; and acetylene has been shown to have been present in plants at the time of explosions.

The actual mode of initiation involved in reported explosions has not been as satisfactorily established.

Recently at least two explosions have occurred in which materials other than acetylene were the primary fuels.

What Happens to Air Contaminants When They Get Into Oxygen Plants

Air is one of the safest of industrial raw materials, yet, it is, at times, the carrier of contaminants responsible for hazards in air separation plants.

Petrochemical and metallurgical industries, for example, which require the products of air separation, are also producers of by-products in the form of waste gases and vapors whose properties would permit accumulation in cold portions of air plants. The design and operation of such plants takes into consideration the local air contaminant problem.

It is helpful to review the course of a few parts per million of contaminants through an air plant. Specific designs alter cases, but some generalizations are possible:

Optimum air intake location is assumed. Prepurification systems play a strong role in contaminant removal, often beyond those impurities for which the systems are specifically designed. Moisture removal in traps associated with compressor intercoolers and aftercoolers is often accompanied by removal of substantial fractions of soluble compounds such as ammonia acetone, ethyl alcohol and others condensible with water.

Caustic scrubbers remove substantially all acidic compounds, such as H_2S, HCN, and most of the NO_2.

Adsorptive driers remove heavy hydrocarbons including residual compressor oil along with water. Medium hydrocarbons such as pentane, hexane, and other organic vapors are largely removed.

Still other residuals in the air feed can pass into the main exchange system. Compounds that boil above 90° F. and freeze above −270° F. (see Table 1) should theoretically be effectively condensed and remain in the exchanger until defrost. In practice, small quantities are often carried on as suspended particles in the air stream. Propane and propylene, which remain liquid below −280° F., are normally carried through the main exchanger. Butanes and butenes, if present as mixtures, are probably also carried (as liquids) beyond the main heat exchange system.

In some plants reversing heat exchangers, or reversing regenerators, are employed instead of shell-and-tube heat exchangers for all or part of the air feed. The air feed goes directly to the reversing equipment without removal of moisture or carbon dioxide and other acidic components. These freeze out in cooling but are, in turn, evaporated on reversal by return oxygen or nitrogen product. The only difference is that a slightly greater fraction of acid gases will go beyond reversing equipment into the high pressure column.

To generalize, nearly all hydrocarbons up through butane and butylene (excluding butadiene and methyl acetylene) would enter the high pressure column, as would NO, N_2O, CO, ozone and hydrogen. Of these, hydrogen and some of the CO would leave the high pressure column with the relatively pure nitrogen overhead and the remainder leave in the crude oxygen bottoms which proceed to the low pressure column.

Carbon monoxide and hydrogen leave the top of the low pressure column with the nitrogen, and all other components must be disposed of via the oxygen.

How Contaminants in Liquid Oxygen Are Removed

In plants where the product oxygen is withdrawn from the reboiler as a liquid, such as in liquid oxygen plants and pumped oxygen plants, the materials remaining in the liquid oxygen are continuously withdrawn. In the former, they are removed from the plant in the liquid while, in the latter, they are vaporized homogeneously with the oxygen at the elevated pressure and correspondingly higher boiling point of oxygen.

Why Absorbers Are Included

Complete vaporization of contaminants with oxygen can be expected for some plant locations, but not relied upon in all instances. Accordingly, hydrocarbon adsorbers are provided to remove contaminants. Effectiveness of removal is high for acetylene and C_3+ hydrocarbons, intermediate for ethane and ethylene. In addition, the adsorbers are effective for removal of organic compounds and virtually all inorganic contaminants except carbon monoxide. Inorganics removed definitely include oxides of nitrogen. The lowest boiling of these is nitric oxide, but this material is said to form nitrogen peroxide (NO_3) with oxygen at these low temperatures (*17*). Any NO not so converted would then be converted to nitrogen tetroxide and adsorbed as such due to the catalytic action of the silica gel; indeed, silica gel has been employed for this purpose at much higher temperatures (*18*).

Methane is the only contaminant that can reach the reboiler unaffected by scrubbing and drying, freeze-out, or hydrocarbon adsorbers. Small fractions of many other components may run the gamut, but the original quantities will have been greatly reduced.

Catalytic Oxidation Offers Promise

Kinder suggested (*19*) in 1924 catalytic combustion of flammable impurities in air to render them in-

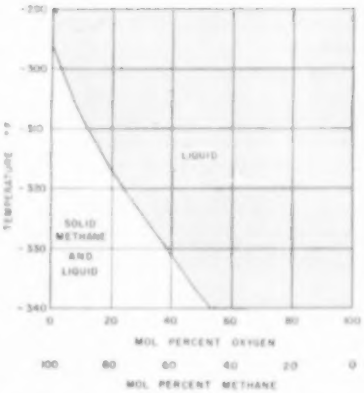

Fig. 1. Methane—liquid oxygen phase system.

Table 1.—Properties of Some Air Contaminants

Name	Formula	Normal boiling point, °F.	Freezing point, °F.
Carbon Monoxide	CO	−312.6	−337.1
Methane	CH_4	−258.6	−296.4
Nitric Oxide	NO	−241.0	−262.6
Ozone	O_3	−169.6	−420
Ethylene	C_2H_4	−154.8	−272.5
Ethane	C_2H_6	−127.6	−297.9
Nitrous Oxide	N_2O	−127.2	−131.6
Acetylene	C_2H_2	−119 (sublimes)	−114.6
Hydrogen Sulfide	H_2S	−75.4	−122.0
Carbonyl Sulfide	COS	−58.3	−217.8
Propylene	C_3H_6	−53.8	−301
Propane	C_3H_8	−43.7	−305.8
Formaldehyde	H_2CO	−5	−180
iso-Butane	C_4H_{10}	10.9	−255.3
iso-Butylene	C_4H_8	19.6	−220.5
1,3 Butadiene	C_4H_6	24.1	−164
n-Butane	C_4H_{10}	31.2	−217.0
Ethylene Oxide	C_2H_4O	51.01	−170.4
Acetaldehyde	CH_3CHO	68.4	−190.3
Nitrogen Dioxide	NO_2	70.3	15.3
n-Pentane	C_5H_{12}	97.1	−204
Acetone	CH_3COCH_3	133.7	−139.0
Methanol	CH_3OH	148.4	−144.0
Hexane	C_6H_{14}	156.2	−137.7
Benzol	C_6H_6	176.0	41.9
n-Decane	$C_{10}H_{22}$	345.2	−23.8

Table 2.—Solubility of Various Materials in Liquid Oxygen at −320° F. (22)

Substance	Solubility in ppm
Methane	740,000
Ethane	92,000
Propane	45,000
n-Butane	150
n-Pentane	20
n-Hexane	2
n-Decane	0.6
Acetylene	1.7
Ethylene	1,800
Propylene	2,500
Acetone	1.5
Methanol	12
Ethanol	15
Acetaldehyde	0.4
Benzene	4
Hydrogen Sulfide	50
Nitrous Oxide	70 *
Carbonyl Sulfide	28 *
Nitrogen Tetroxide (N_2O_4)	15 *
1-3 Butadiene	20 *

* at −297° F.

In low pressure "gas" plants, where the product is withdrawn from the low-pressure column as a gas, methane builds up to an equilibrium value in the reboiler condenser (also called "vaporizer") and is thereafter vaporized with the oxygen. As hydrocarbon chain length increases (and vapor pressure decreases), the equilibrium concentrations necessary to maintain hydrocarbon balance via vaporization are sharply increased. At high rate of hydrocarbon input, these concentrations can exceed the solubility limit or the lower explosive limit, resulting in hazardous conditions. Burbo and Ishkin (*12, 13*) have discussed the maximum level of acetylene which can be carried off without exceeding the solubility limit.

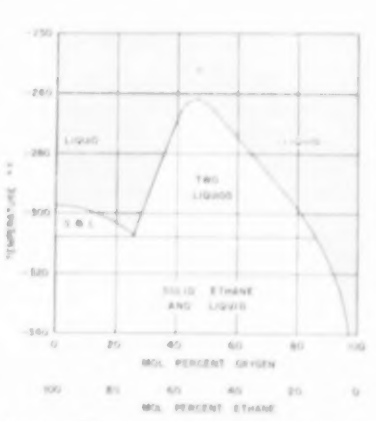

Fig. 2. Ethane—liquid oxygen phase system.

noxious. Until recently this has been considered to be an uneconomic procedure, but we can envisage that air contaminations will, in some localities, reach levels justifying this method. Kerry (*16*) has again advanced this proposal and discussed development of catalysts.

One supplier (*20*), and probably others, can now offer a catalytic unit for virtually complete removal of acetylene by oxidation to carbon dioxide and is continuing work on other hydrocarbons. For acetylene, this apparatus operates in the range of compressor discharge temperatures.

Higher catalyst temperatures (*20, 21, 22*) are required for oxidation of hydrocarbons other than acetylene. Experimental data are available for methane, ethane, ethylene, propane, propylene, butene, and benzene. This information indicates that complete oxidation of all hydrocarbons can be secured at a temperature of 800 to 900° F., a more costly temperature level to maintain. However, all but one hydrocarbon, methane, can probably be substantially oxidized at lower temperature, perhaps between 500 to 600° F.

In the material that is presented in this paper it will be shown that oxygen plant tolerance for methane is high indeed, since oxygen containing as much as several per cent of methane is not explosive. This means that methane removal as a contaminant, up to quite high concentrations, is not required for safe operation. The catalytic treatment of air for hydrocarbon oxidation is therefore effective somewhat below 100 per cent oxidation, as oxygen plants have some tolerance to contaminants. Monitoring permits a new freedom in the use of catalytic air treatment.

Explosion Characteristics

Predictability of the effects of liquid oxygen-fuel explosions is frequently difficult or impossible. The combustion phenomena are far out of the ordinary due to the high density of reactants, the liquid phase containing hundreds of times as much material per unit volume as would be present in the gas phase. Acetylene explosions in liquid oxygen are highly brisant (shattering in effect).

There is much literature (*23*) relating to combustion and explosion of gases and solids, but very little which treats of the same phenomena in liquids. Some generalizations, how-

HISTORY

Thousands of air separation plants have been operated in many different industrial atmospheres during the past decades and have achieved a creditable safety record. Infrequent explosions have taken place in a few of these plants; some of these have been described and discussed in published articles.

Brankamp, in 1914 (*1*), summarized the character of several explosions which had occurred up to that time, ascribing them to mixtures of oxygen with combustible insulation or acetylene. His paper included speculation upon the role of copper acetylide, compressor oil (and its decomposition products), hydrogen and methane atmosphere contaminants, electrical phenomena, ozone, ozonides, and peroxides.

In 1923 Pollitzer (*2*) published a comprehensive paper describing a number of explosions and presented experimental work which sought to elucidate the explosion mechanism. His survey disclosed that air plant explosions invariably took place in the oxygen evaporating equipment, that is, in the reboiler or in the oxygen evaporating coils; that the plant on-stream time could not be evaluated as a factor; that explosions occurred generally during operation, some after a few hours only, some after many weeks; that still others took place after shutdown. He considered ozone, acetylene, and lubricating oil as sources of energy and considered mechanical agitation as a source of ignition, either directly or through augmentation. He carried out experiments in which solid acetylene was suspended in liquid air or oxygen, demonstrating that such mixtures could explode. Pollitzer further studied specific air plant explosions and found either proof or strong evidence that acetylene was present at the time of each explosion. His work resulted in a clear understanding that acetylene is a hazard.

Fyleman, in 1923 (*3*), emphatically concluded that acetylene caused air plant explosions. He produced acetylene experimentally from oil in simulated air compression, showing that the air compressor itself can be a source of acetylene entry into an air plant, even in an uncontaminated atmosphere. The precautions of avoiding hot spots in the compressors, of using suitable oil, and of banning carbide from the neighborhood of the plant are listed as being proven through experience to provide adequate protection. In a large Norwegian plant liquefying about 100 tons of air per day, where the air was aways contaminated with acetylene and where effects of explosions had previously been serious, it was found that explosions were eliminated by withdrawing (from the reboiler) a bucketful of liquid oxygen every hour and throwing it away.

Some discussion and review papers, such as that by Berger (*4*), appeared in subsequent years, but significant and pertinent new experimental evidence was not added to the literature until the 1940's. A publication by Strizhevskii (*5*) was one of the first papers in a series of several valuable contributions appearing in the Russian literature. These papers, taken as a group, treat the solubility of several hydrocarbons in liquid air, the adsorption of hydrocarbons upon silica gel, and the use of this information in air plant design. Strizhevskii's review is a good summary of the state of the art in 1939.

Ishkin, Burbo, Tsin, Fedorova, Fastovskii, and Krestinskii, jointly and individually, have reported upon the solubility of acetylene (*6, 8*), of carbon dioxide (*6, 8*), of ethylene (*7*), of propylene (*7*), and of methane (*9*) in liquid oxygen and in liquid nitrogen, and upon the vapor pressure of solid acetylene (*10*). In 1940, Ishkin and Burbo (*11*) reported experimental data for the adsorption of acetylene upon silica gel from a flowing stream of liquid air. Burbo (*12*) and Ishkin and Burbo (*13*) round out the Russian contributions with a discussion of acetylene accumulation and distribution in an air plant and with a description of the use of silica gel adsorbers for removal of acetylene from operating plants.

Cox and DeVries (*14*) reported experimental work from Purdue University upon the solubility of solid ethane, ethylene, and propylene in liquid nitrogen and oxygen.

Until the last decade, the literature has cited acetylene as the chief culprit or suspect. This view has been remarkably and demonstratively successful in reducing and eliminating hazards. The actual initiating mechanism has remained substantially unknown. Many factors have been recognized as having potential roles as initiators, but basic experimental work has not been reported until recently. Nomura and Kanda (*15*), working in the Research Institute for Iron, Steel and Other Metals, Tohoku University, have demonstrated that an explosion occurs when ozone is contacted with ethylene or acetylene at low temperatures. An understanding of the mechanism of the reaction of ozone with unsaturated hydrocarbons was their objective.

Recently, Kerry (*16*) summarized many aspects of air plant contamination and discussed safe design and operating practices.

ever, may be tentatively made, subject to experimental evaluation. In the gas phase, a distinction between *combustion waves* and *detonation waves* may be drawn. A combustion wave is propagated through the combustible mixture by heat transfer and diffusion. A detonation wave is propagated by the energy of the chemical reaction taking place in the highly compressed shock wave; the shock wave raises the energy level of the reactants, preparing them for the chemical energy release which, in turn, provides the energy for continuation of the shock wave. Combustion waves are slow, of the order of several feet per second; detonation waves are faster than the speed of sound, of the order of several thousand feet per second. Either type of combustion may take place in an explosive mixture, depending upon many factors such as mixture composition, mixture density, and confinement. A detonable mixture may be made richer or leaner in fuel until the upper and lower limits of detonability are reached. As the mixture is made still richer or leaner beyond these limits, upper and lower limits of inflammability are reached. The detonation phenomena are dependent upon factors such as volume and shape of container and type of initiation.

The foregoing generalizations apply to homogeneous gas fuel-oxidant mixtures. Much of the above general understanding of combustion in gases may be directly used in describing combustion phenomena in liquid oxygen. In liquid oxygen-fuel mixtures which are single phase, we may expect to observe experimentally upper and lower limits of detonability and inflammability, as is the case with single phase gaseous mixtures of air or oxygen with fuel.

Similar to gas phase combustion, the predictability of the character of combustion becomes less certain as the liquid system becomes two-phase. Dusts and mists suspended in air are uncertain in behavior due to the lack of uniformity of dispersion and to the variation in particle size. Likewise, suspensions of solid or liquid combustibles in liquid oxygen are nonuniform and their behavior as combustibles is uncertain.

Explosion Prevention

Pure oxygen—gas and liquid—can be handled and processed without fear of combustion. Explosive mixtures of combustibles with oxygen do not automatically explode. Some source of ignition energy is required. This does not imply that fuel-oxygen mixtures should be permitted to accumulate or persist in air plants, for given sufficient time, the source of ignition may well appear.

The oxygen-fuel-initiator combination must be avoided. Oxygen, of necessity, is present; possible initiator mechanisms are many, and positive control extremely difficult; control of fuel accumulation controls the situation and avoids the hazard. Prevention of fuel accumulation is the safest solution of the air plant hazard potential. The avoidance of fuels does not mean that initiators are to be ignored; it is merely a recognition that in the absence of fuels, the initiators become impotent.

Plant safety may be maintained through sound design and operational principles by the recognition of the following:

1. **Explosiveness is predictable from mixture composition.**
2. **Composition of plant streams can be monitored during operation.**
3. **Careful design and operating techniques based on experience and appraisal of the problem can anticipate and prevent explosive concentrations.**

Let us now consider in more detail some of the implications involved in avoidance of oxygen plant hazard through contaminant control. The three elements listed above will be examined in turn. First, what are the conditions which determine explosiveness; what are the conditions which allow explosiveness to be predicted and, hence, avoided?

Conditions of Hazard

For any combustible there is some level of concentration in liquid oxygen above which the mixture is hazardous and below which it is not. For the highly soluble ones this is the flammable limit; for the less soluble ones the limit is, to all practical purposes, the solubility.

The flammable limit is self-evidently to be avoided. The significance of solubility becomes evident when one considers that levels above the solubility limit can result in localized concentrations of fuels above the lower explosive limit. This is possible even though the total quantity of fuel with respect to the total quantity of oxygen is below the flammable limit. Thus, if either the explosive limit or the solubility limit is exceeded, a hazardous condition exists. Accordingly, if either of these limits are approached, corrective measures are indicated. Solubility values for a number of materials in liquid oxygen at −320° F. are given in Table 2, and in Figures 1 and 2. Discussion of these data appears later.

The lower explosive limits of hydrocarbons can be expressed as methane equivalent. When this is done, the numerical values lie within a comparatively narrow range. This permits a

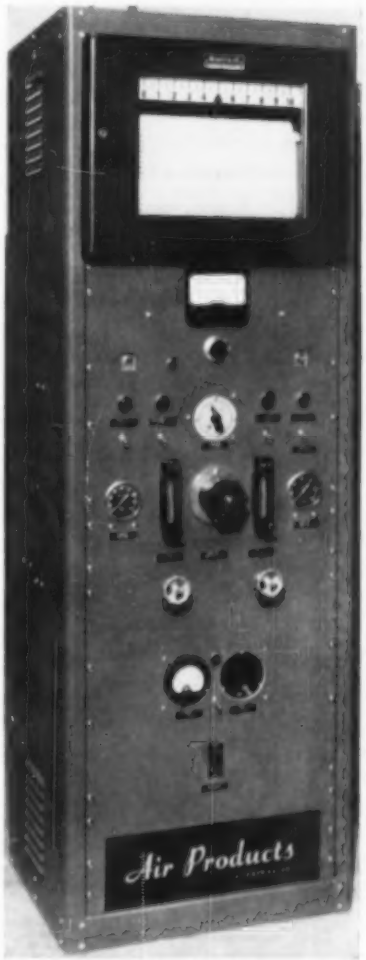

Fig. 5. Continuous Total Hydrocarbon Analyzer.

first approximation of explosive limits for mixtures, which is useful since the energy release per unit mass at the lower flammable limit is roughly the same for all hydrocarbons. In Table 3, a comparison is drawn among several hydrocarbons, of lower gas phase flammable limit, energy release per gram mole of mixture, and lower flammable limit expressed as methane (approximated by multiplying the lower explosion limit by the number of carbon atoms in the molecule). It will be seen from experimental explosion test data presented in the following section that the lower explosive limit for gas phase mixtures of hydrocarbons and oxygen is useful for liquid mixtures of the soluble hydrocarbons.

Experimental Explosion Test Data

In Table 4 are summarized some representative data from Lewis and von Elbe (*23*) which relate detonability and flammability limits for certain gaseous single-phase fuel-oxidant mixtures. Detonability limits are composition-wise within the flammability limits. The lower flammability and detonability limits are roughly the same for the mixture of the fuel with either air or oxygen. This qualitative similarity is due, no doubt, to the fact that excess oxidant is present in either case. The upper limits, however, differ markedly from air to oxygen.

It is of interest to compare the behavior of a liquid oxygen-methane mixture with the corresponding gaseous data. Oxygen and methane form a single-phase liquid system at temperatures above the freezing point of methane, as is shown in Figure 1, and at much lower temperatures it is still possible to prepare very concentrated single-phase mixtures. Due to this great solubility, it is possible to observe experimentally both the lower explosive limit and the upper one. Following the technique described in another section of this paper, it has been found (*22*) that the lower explosive limit in the liquid oxygen-methane system of 11 mole per cent methane and the upper explosive limit of 50 mole per cent methane fall within the gas phase limits of 5.4% and 59.2%. The lower explosive limit of ethane has been observed, using flash bulb initiation with the unprotected bulb directly immersed in the ethane-liquid oxygen mixture, and found to be about 4 mole per cent ethane. This system has an upper explosive limit which can be observed only at such elevated system pressures as those which permit a single liquid phase to exist. The liquid phase explosion limits for methane and for ethane are thus seen to be consistent with the gas phase data for the same systems.

Selected data from a comprehensive experimental explosion testing program under way at Air Products (see Experimental Explosion Testing Techniques) are presented in Table 5.

The first eleven tests encompass both the high and low explosion limits for the CH_4—O_2 liquid system. The same results are obtained at both liquid nitrogen and liquid oxygen temperatures. The lower explosion limit

Table 5.—Experimental Explosion Test Data

Test No.	Composition of test mixture, mole %	Vol. of condensed sample, cu.cm.	Test container	Initiation	Remarks
1	4 CH_4—96 O_2	15	⅜" O.D. × 6" long copper tube	Blasting cap	No explosion
2	5 CH_4—95 O_2	200	250 cc. glass flask	Blasting cap	No explosion
3	7 CH_4—93 O_2	30	1" O.D. × 4" long copper tube	Blasting cap	No explosion
4	10 CH_4—90 O_2	90	1¼ O.D. × 7" long copper tube	Blasting cap	No explosion
5	12 CH_4—88 O_2	30	1" O.D. × 4" long copper tube	Blasting cap	Exploded
6	15 CH_4—85 O_2	30	1" O.D. × 4" long copper tube	Blasting cap	Exploded
7	33.3 CH_4—66.7 O_2	30	1" O.D. × 4" long copper tube	Blasting cap	Exploded
8	50 CH_4—50 O_2	14.5	⅜" O.D. × 6" long copper tube	Blasting cap	No explosion
9	50 CH_4—50 O_2	16	⅜" O.D. × 6" long copper tube	Blasting cap	Exploded
10	55 CH_4—45 O_2	30	1" O.D. × 4" long copper tube	Blasting cap	No explosion
11	69 CH_4—31 O_2	15	⅜" O.D. × 6" long copper tube	Blasting cap	No explosion
12	100 N_2O slurried in liquid oxygen	Solid	50 cc. test tube	Blasting cap	No explosion
13	100 N_2O	Gas at 70° F.	1 gallon can	Blasting cap	Exploded
14	100 N_2O	Gas at 70° F.	1 gallon can	M-2 flash bulb, plastic removed	Exploded
15	100 NO_2	Gas at 70° F.	1 gallon can	M-2 flash bulb, plastic removed	Exploded
16	100 NO_2	Solid	50 cc. test tube	M-2 flash bulb, plastic removed	Slurried in liquid oxygen, no explosion
17	50 C_2H_4—50 O_2	10	20 cc. test tube	Ozone	O_2 with 0.1% O_3 was bubbled through test mixture while applying mechanical shock, no explosion
18	Solid C_2H_4 floating in liquid oxygen	10	22 cc. test tube	Ozone	O_2 with 0.1% O_3 bubbled into test mixture. Immediately exploded.
19	Solid C_2H_4 floating in liquid oxygen	30	1" O.D. × 4" long copper tube	Blasting cap	Exploded
20	Solid oil slurried in liquid oxygen	135	250 cc. round bottom flask	Blasting cap	Exploded. Much oil unreacted.
21	Tricresyl phosphate lubricant, slurried in liquid oxygen	100	250 cc. round bottom flask	Blasting cap	Exploded
22	Polyethylene glycol lubricant, slurried in liquid oxygen	100	250 cc. round bottom flask	Blasting cap	Exploded
23	3.1 C_2H_6—96.9 O_2	10	1" O.D. × 4" long copper tube	M-2 flash bulb	No explosion
24	4.4 C_2H_6—95.6 O_2	10	1" O.D. × 4" long copper tube	M-2 flash bulb	Exploded
25	3.1 C_2H_6—96.7 O_2 + 0.2 NO_2	10	1" O.D. × 4" long copper tube	M-2 flash bulb	No explosion
26	Solid C_2H_4 in liquid oxygen	10	10 mm. glass test tube	Ozone	O_2 with 0.1% O_3 bubbled into test mixture. No explosion.

Table 3.—Gas Phase Flammable Limit—Carbon Atom Approximation

Compound	Formula	Lower limit, mole %	Lower limit, as methane, mole %	Heat of combustion, K cal./mole	Energy release at lower limit, K cal/gm mole of mixture
Methane	CH_4	5.00	5.00	213	10.16
Ethane	C_2H_6	3.00	6.00	373	11.2
Propane	C_3H_8	2.12	6.36	531	11.3
Butane	C_4H_{10}	1.86	7.44	688	12.8
Pentane	C_5H_{12}	1.40	7.0	845	11.8
Hexane	C_6H_{14}	1.18	7.08	1002	11.8
Nonane	C_9H_{20}	0.83	7.47	1473	12.2
Decane	$C_{10}H_{22}$	0.77	7.7	1630	12.6
Ethylene	C_2H_4	2.75	5.5	337	9.2
Propylene	C_3H_6	2.0	6.0	492	9.8
Butene-1	C_4H_8	1.65	6.6	650	10.4
Acetylene	C_2H_2	2.50	5.0	311	7.6
Toluene	C_7H_8	1.27	8.9	944	12.0
Benzene	C_6H_6	1.4	6.4	789	11.0

Table 4.—Flammability and Detonability Limits—Gases (17)

Mixture	Lower limit, mole %		Upper limit, mole %	
	flammability	detonability	detonability	flammability
H_2—O_2	4.65	15	90	94
H_2—air	4.0	18.3	59	74
CO—O_2 (moist)	15.5	38	90	93.9
CO—air	12.5	....	....	74.2
CH_4—O_2	5.4	....	....	59.2
CH_4—air	5.0	....	....	15.0
C_2H_2—air	2.5	4.2	50	80
$C_4H_{10}O$ (ether)—O_2	2.1	2.6	>40	82
$C_4H_{10}O$—air	1.85	2.8	4.5	36.5
C_2H_4—O_2	4.10	....	....	50.5
C_3H_8—air	3.0	....	....	12.5

is about 11 mole per cent methane and the upper 50 mole per cent methane, with the confinement and initiation indicated in Table 5. It is expected that more powerful initiation than provided by a blasting cap would extend these limits slightly.

Nitrous oxide, N_2O, which has an endothermic heat of formation, is exploded by a blasting cap, as an atmospheric pressure gas at 70° F., but is not explosively decomposed by such initiation when frozen solid and at liquid oxygen temperatures.

Oils and other insoluble hydrocarbons, slurried in liquid oxygen, may be exploded by a blasting cap. Explosions involving dissolved fuels under identical conditions have a higher combustion efficiency and are more brisant due to the greater intimacy of fuel-oxygen contact.

Addition of 2,000 ppm of NO_2 to an ethane-oxygen liquid system just below the lower explosive limit of ethane produces no explosion.

Ozone, at a low concentration in oxygen, when introduced into a slurry of acetylene in liquid oxygen, immediately produced an explosion. When introduced into a slurry of ethylene in liquid oxygen it did not produce an explosion.

Explosion Initiators

Only meager knowledge of the forces which initiate explosions in oxygen plants is available. Despite this handicap, constructive recommendations can be made to minimize some modes of ignition. Because of this handicap, we have no assurance that there may not be unknown mechanisms of ignition not covered by the recommendations.

It is well known that discharges of either static electricity or mechanical shock can initiate explosion of a sensitive material. To minimize these, excessive impingement velocities and vibration should be avoided.

It is quite possible that some oxygen plant explosions have been initiated by obscure chemical reactions. Ozone has been under suspicion in this regard. Experimentally, gaseous mixtures of oxygen and acetylene or ethylene have been ignited by addition of ozone (*15*). A slurry of solid acetylene in liquid oxygen has also been ignited by ozone (*22*). It is probable that the initiator in this particular case is a highly shock-sensitive ozonide of acetylene.

Oxides of nitrogen are atmospheric pollutants that have been under suspicion. Accordingly, attempts have been made to ignite hydrocarbon-liquid oxygen mixtures by addition of nitrous oxide, nitric oxide, and nitrogen dioxide. To cite one experiment, an explosive mixture of methane, acetylene, ethylene, and butadiene was added to liquid oxygen and then both nitric oxide and nitrogen dioxide added. This mixture boiled for several hours without event, until detonated by a blasting cap. Such findings, together with an observation that at least one plant has operated safely at a high level of nitrogen oxide contamination (*21*), are interesting but are by no means conclusive.

Nitrogen tetroxide, N_2O_4, does react with unsaturated hydrocarbons (*25*) and explosive compounds can result (*26*). This tetroxide is readily formed from either nitric oxide or nitrogen dioxide by the reactions:

$$2NO + O_2 = 2NO_2$$
$$2NO_2 = N_2O_4$$

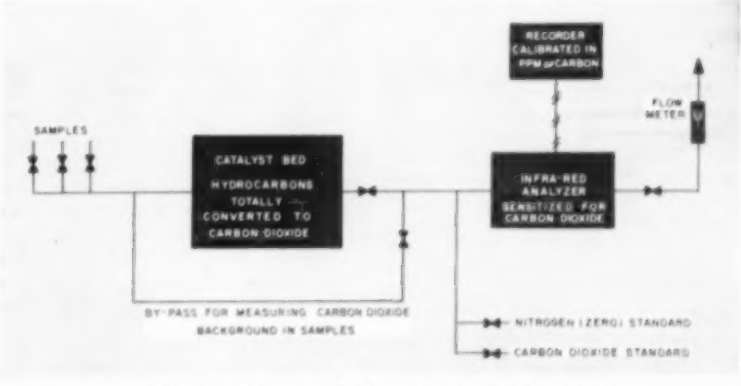
RECORDER CALIBRATED IN PPM of CARBON
FLOW METER
SAMPLES
CATALYST BED
HYDROCARBONS TOTALLY CONVERTED TO CARBON DIOXIDE
INFRA-RED ANALYZER SENSITIZED FOR CARBON DIOXIDE
BY-PASS FOR MEASURING CARBON DIOXIDE BACKGROUND IN SAMPLES
NITROGEN (ZERO) STANDARD
CARBON DIOXIDE STANDARD

Fig. 4. Schematic diagram of Continuous Total Hydrocarbon Analyzer.

When coke oven gas is cooled, a resin is deposited, which has occasionally exploded in main heat exchangers. These resins are believed (*27*) to be formed from nitric oxide or nitrogen dioxide and olefins which are present at a level over one per cent. Neither these resins nor anything resembling the same type of explosion is known to have occurred in an air plant. Indeed, such an occurrence is unlikely because even a refinery atmosphere could contain little more than a minute fraction of the olefin concentrations in coke-oven gas.

The possibility of such intermediates acting as initiators is not completely excluded.

Thus, we see that ozone is a plausible initiator of oxygen plant explosions, but two oxides of nitrogen (NO and NO_2) remain subjects of conjecture. There may well be other manners of ignition of which we have no knowledge.

It would be desirable to remove all components that could possibly become a source of ignition. The obvious method of removal is to install an adsorber in the crude oxygen line to remove material more strongly adsorbed than oxygen, nitrogen, and argon. Since nearly all air contaminants boil well above these, such a method should work. In case the adsorbers do not control the offenders, the next obvious step is to drain liquid oxygen and discard it until the level of contamination is again reduced to a safe level.

Regardless of the method of initiation, no explosion can occur without fuel. This means we must emphasize prevention of hazardous fuel levels as the first line of safety defense. As we learn more about initiators, monitoring means may be applied.

Due to the lack of fuller knowledge on initiation, our second line of defense—preventing ignition—is a weak and unreliable one.

From a recent paper by Lewis entitled "Industrial Explosion Hazards Detection" (*28*) we quote:

> "Knowing that potentially hazardous conditions are likely to exist, one may accept them and attempt to prevent their activation. Obviously, some idea of the ease of initiation of violent phenomena is needed. . . . Usually a more realistic approach, when the difficulty of identifying all possible means of initiation is thought out, is to prevent the conditions which permit the development of propagation of explosive reactions."

Monitoring

Plant streams can be monitored during operation and the level of contamination so determined. This level measures the approach to a hazardous condition. Monitoring techniques vary with the particular situation. Process cycle, design features, atmospheric environment, and onstream requirements all affect the monitoring procedures which are selected. Relatively stringent standards may prudently be set for plant startup. These may be modified as permanent "ground rules" are established through on-site plant experience.

The air separation plant in which the entire oxygen product is withdrawn from the reboiler as a liquid combines a minimum of process design and operating precautions. The liquid may be the final product or it may be pumped to elevated pressure and vaporized by heat exchange. In such plants, the opportunities for accumulations of contaminants are minimized, reducing hazards. If plants produce some or all of their oxygen as a low pressure gas taken from the column, both plant design and plant operation become more critical. If these plants, in addition, are located in industrial areas where the concentration level of contaminants may be unusually high, the need for monitoring is increased.

The variable nature of air pollution must be considered in the formulation of sound design and operating procedures. Allowance must be made for temporary surges in contamination greatly exceeding the typical values. Thus, on rare occasions, the pollution levels may override the design safety factors and corrective procedures such as drainage of liquid oxygen, shortening the hydrocarbon adsorber cycle, and emergency shutdown may be required. Continuous monitoring affords necessary guidance in such contingencies.

Safety through monitoring requires the establishment of safe operating limits of concentration. Using the approximation that the lower flammable limit, expressed as methane or carbon atom equivalent, is reasonably constant and above 5 mole per cent, a value such as 500 ppm (safety factor—100:1) may be adopted as a tolerable level for soluble contaminants. The value used in a particular situation is dependent upon appraisal of the individual plant contamination spectrum, this appraisal being typically a cooperative effort of the air separation plant supplier with the future plant operator. The utility of the carbon atom equivalents approximation as a measure of hazard and the possibility of sudden variation in atmospheric contamination support continuous total hydrocabon analysis as a basic feature of the monitoring program.

Continuous Hydrocarbon Analysis

A continuous total hydrocarbon analyzer has been developed (*22*) which is sensitive to any hydrocarbon (or other organic combustible) without discrimination. (See Figures 4 and 5).

The apparatus provides a means for continuously analyzing air plant streams for very low concentrations of carbon-containing impurities. In principle, the apparatus parallels classical carbon analysis by oxidation of combustible material to carbon dioxide and determining the latter. In this apparatus, the hydrocarbons in the sample stream are completely oxidized over a catalyst, and the resultant carbon dioxide analyzed by a sensitive infra-red analyzer.

The sample introduction may conveniently be sequence-timed to assure uniformly repetitive examination of several different sample streams. This, in effect, affords, with the one instrument, a substantially continuous trace for each sample. A typical strip chart record from the analyzer is shown in Figure 6.

The choice of samples for monitoring is somewhat dependent on the air plant cycle, but a sample which is representative of reboiler conditions usually affords the most useful information for effective fuel control. The air feed, after compression and drying, is often sampled to indicate the level of fuel entering the plant. Air feed sampling is more significant in liquid oxygen or liquid pump plants where the reboiler concentration does not exceed five times that of the incoming air. In plants producing low pressure gaseous oxygen, of course, the reboiler accumulations will be dependent upon the vapor pressures of each contaminant and the amount of liquid oxygen withdrawn as a purge.

For additional information, occasional samples are taken from exchanger defrosts, from adsorber reactivation gas, from liquid purges and other points—some of which are unique with specific cycles. These samples are generally not essential in fuel control but provide supplementary information for diagnostic purposes.

It is evident that, although continuous total hydrocarbon analysis is an invaluable aid, an understanding of the relative amounts of the individual contaminants is also needed. A total hydrocarbon level of 200 ppm is safe only if no hydrocarbons with a solubility limit below 200 ppm are present in excess of their individual solubility limits.

Acetylene is one of the few troublesome hydrocarbon contaminants having a very low solubility. Because of

its low solubility and its reactive character it must be monitored separately. Usually this is done by a special Ilosvay test made at scheduled times. Such scheduled tests for acetylene are adequate so long as results remain convincingly low. A set of typical rules employed in many well-run plants over the years is as follows:

Above 0.2 ppm, tests should be frequent.

Above 0.5 ppm, corrective measures should be taken.

Above 2 ppm, the plant should be shut down.

The adequacy of this approach is reflected in the excellent safety record enjoyed by producers of cylinder gases. Acetylene is also detectible by infrared techniques; such instruments are commercially available for continuous monitoring.

Individual analyses also serve in diagnosis of exact causes of "peaks" or "high plateaus" in the total combustible trace. To this end, the gas chromatograph using the adsorption or partition column, or both simultaneously, is a very convenient tool. Following concentration, samples as small as 0.05% of a component can be analyzed in a positive and quantitatively reproducible manner in a few minutes. The mass spectrometer, infrared spectroscopy, distillation, and other standard techniques of gas analysis also serve. Some specific tests for non-hydrocarbon contaminants are indicated in Table 6.

Extension of some of these analytical methods in the ppm or even into the ppb (parts per billion) range is facilitated by sample concentration using a low temperature adsorption technique. Atmospheric samples, for example, can be concentrated in a train consisting of a dry pump, a CO_2 scrubber, a drier, an adsorption cell containing silica gel at liquid oxygen temperatures, and a wet test meter. After passing the necessary quantity of air through the sampling system, the adsorbed sample is quantitatively transferred into a gas measuring burette in preparation for analysis.

Some plant operators conduct scheduled total hydrocarbon or individual hydrocarbon analyses on a batch sampling basis to provide assurance of safe operation in their particular environment. Others employ continuous observation as their best solution.

Primary concern for protection and, hence, most extensive monitoring, must be applied where the most susceptible cycle is being operated in the most unpredictable atmosphere. Least extensive monitoring is necessary where the liquid pump plant is oper-

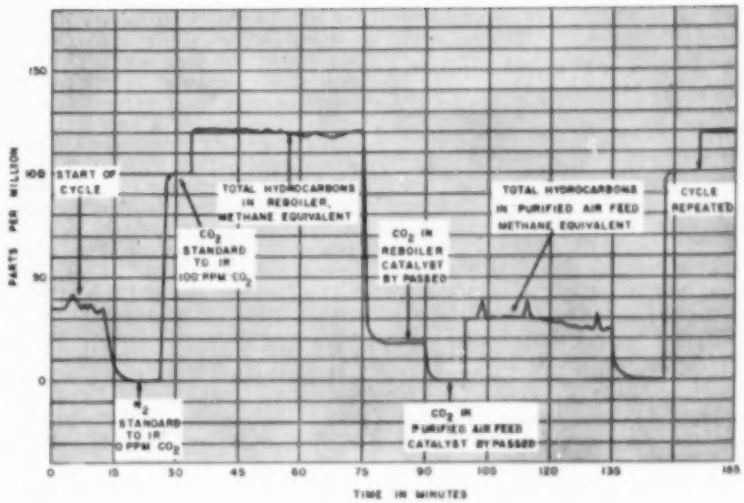

Fig. 6. Sample strip chart from Analyzer showing operating cycle.

Table 6.—Type of Contaminant Analyses

Compound	Method of Analysis
Acetylene	After concentration by low temperature freezeout, detect colorimetrically with Ilosvay solution (30).
Carbon dioxide	After low temperature concentration and absorption in excess barium hydroxide, back-titrate with acid (31).
Carbon monoxide	a) After CO_2 removal, concentrate at low temperatures, oxidize to CO_2 and proceed as above, for CO_2. b) Colorimetric analysis by palladous sulfate and ammonium molybdate (32).
Hydrogen sulfide	Following absorption by zinc acetate, convert into methylene blue in solution, measure colorimetrically (33).
Nitric oxide	Following permanganate oxidation, detect colorimetrically with Greiss-Saltzman reagent (34).
Nitrogen dioxide	Colorimetric, with Greiss-Saltzman reagent (34).
Ozone	Numerous methods including use of aldehyde, KI, fluorescein, etc. (35).
General	Following low temperature concentration, methane, individual hydrocarbons, light organics and nitrous oxide may be determined readily by gas chromatography, mass spectrometry, infrared spectroscopy, or Podbielniak distillation.

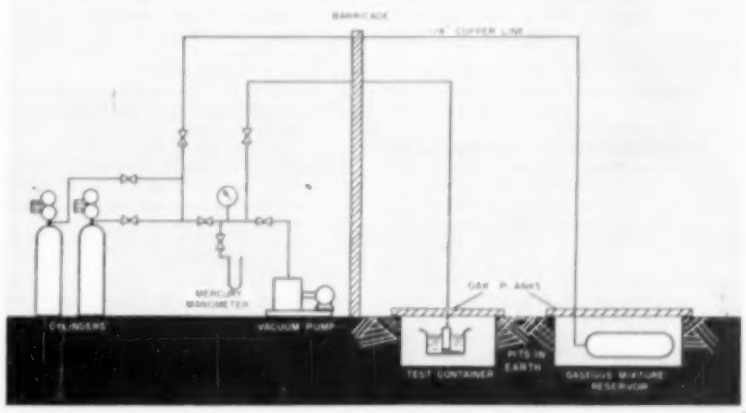

Fig. 3. Explosion testing apparatus.

ated in a continuously clean atmosphere.

In short, the extent of required monitoring practice can be determined only by careful consideration of plant cycle, mode of operation, the atmospheric level of contamination, and knowledge of the properties of the contaminants.

Appendix A

SOLUBILITIES IN LIQUID OXYGEN

Liquid methane is completely miscible with liquid oxygen and, below its freezing point, solid methane is very soluble in liquid oxygen. Data on this are given in Figure 1. The previously published data of Fastovskii and Krestinskii (*9*) have been verified and extended. Physical chemists will be interested in the observation that methane solubilities are in fair agreement with values calculated from the laws of ideal solution (*29*) using the latent heat of fusion of methane corrected for the specific heats of the solid and liquid.

New data on ethane are presented in Figure 2, which is a phase diagram for the ethane and oxygen system. Above about −262° F. liquid ethane and liquid oxygen are miscible; between this temperature and the freezing point (−298° F.) these liquids are only partially miscible. Two liquid phases, one rich in ethane, the other in oxygen, can coexist; in fact, this situation persists below the freezing point down to −308° F. The solid ethane has a high solubility in the ethane-rich phase down to −308° F., but the ethane-rich phase is no longer stable below this temperature, and the equilibrium is then with the oxygen-rich phase to the extent of a reduced solubility.

So far as is known, the complex nature of ethane-oxygen phase equilibria has not been heretofore recognized, although Cox and DeVries (*14*) previously studied this system, and these same authors did note similar behavior of propane and propylene with liquid oxygen.

The solubilities of a number of materials at a single temperature of −320° F. are given in Table 2. It may be noted that nearly all of these values represent original data. The solubilities for many of these are limited to a few parts per million. A description of three experimental methods available follows:

(1) *Turbidity Method.* This technique involves preparing a mixture of the desired concentration of hydrocarbon and oxygen and, subsequently, condensing this mixture inside a glass bulb and noting whether the condensate is one- or two-phase. The concentration of hydrocarbon in the mixture may be gradually changed until successive condensed samples result in a sample being clear, if the concentration of hydrocarbon is being decreased, or cloudy, if the concentration of hydrocarbon is being increased. This visual method of determination, if carefully operated, can be accurate even to 1-2 ppm.

(2) *Freeze-out Method.* This technique can be effected by totally evaporating the contaminated liquid oxygen, passing the vapor stream through a freeze-out trap maintained at liquid oxygen temperatures and so collecting the hydrocarbon or other contaminant. The trap is later evacuated to remove the oxygen completely, leaving only the relatively nonvolatile hydrocarbon. Finally, the trap is warmed to room temperature. The amount of hydrocarbon so isolated in the trap can be calculated through knowledge of the trap volume and the final temperature and pressure in the freeze-out trap. Care should be taken, however, to remove any moisture or carbon dioxide during the preparation of the saturated liquid oxygen solution.

(3) *Infra-red Analyzer Method.* A saturated solution is first prepared and then totally vaporized through an infra-red analyzer. The total dissolved material is determined by integrating these analyzer values. This is applicable when infra-red equipment is available for direct monitoring. Hydrocarbon analyzers of the type described in this paper make it possible to apply this method to any hydrocarbon or any organic chemical. This technique is not a rapid one and requires great care, but is capable of high accuracy.

Appendix B

EXPERIMENTAL EXPLOSION TESTING TECHNIQUE

One experimental approach which has been used (*22*) in evaluating the explosiveness of hydrocarbon-liquid oxygen mixtures is schematically indicated in Figure 3. The system consists essentially of a gaseous mixture reservoir, a test container in its surroundings, and the necessary lines, valves, etc., for the introduction and purging of gases. Some data obtained with this system are listed in Table 5. The apparatus and technique will be described in more detail by describing Test Number 5 of this table.

A copper tube 1-in. O.D. × 4-in. long was closed at each end with flat brass stock, soldered into place, and a ¼-in. copper tube was soldered as a connection to one end. An electric blasting cap was taped to the outside of this tube at the lower end and the assembly centered in the lower part of a gallon can, which in turn was placed in an earthen pit and covered with oak planks. This test container was connected as shown in Figure

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3 to a 2,100 cu. in. gaseous mixture reservoir located in a separate barricaded pit. The system was alternately evacuated and filled with oxygen gas to atmospheric pressure three times. The third time, the exact pressure of oxygen gas in the system as indicated by the mercury manometer was carefully noted. Methane was then added, increasing the total pressure to 1.24 atmospheres. Oxygen, in turn, was added, bringing the total pressure to 2.0 atmospheres, and the mixture allowed to mix by diffusion and convection. The test container portion of the system was then purged three times by evacuation and filling with the 12 CH_4—88 O_2 mixture. The gallon can in which the test container was situated was at this time filled with liquid oxygen and sufficient gaseous mixture allowed to flow from the 2,100 cu. in. reservoir to result in about 30 cu. cm. of liquid condensate in the test container. No composition change takes place during this transfer as total condensation occurs in the 1-in. × 4-in. tube; the quantity of material transferred is noted by pressure drop in the reservoir.

The circuit to the blasting cap was closed and an explosion occurred, bursting the test container and also the liquid oxygen container. The debris was collected from the walls of the pit and saved for comparison with other tests.

The above procedure was modified somewhat when working with liquids and solids and also was modified when the condensed system would consist of more than one phase. The blasting cap initiation was satisfactorily reproducible at liquid air temperatures; other initiation methods employed were: high energy spark, hot wire, fused wire, dropping weight, air gun pellet, M-2 flash bulb, and ozone.

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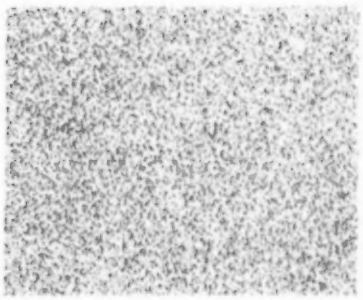
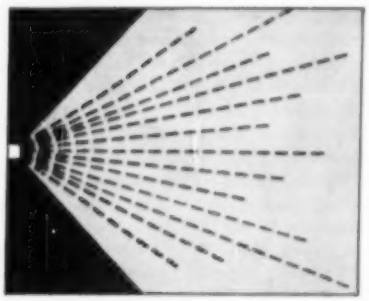


MIST AND SPRAY EXPLOSIONS



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Suspensions of more or less finely-divided liquids in air are commonly formed in two ways: by condensation of saturated vapor, as in the 'steam' issuing from the spout of a kettle or from the relief-valve of a boiler; and by the atomization of liquid due to mechanical forces, exemplified by the many types of spray nozzles and by the break-up of the lubricating oil in an engine crankcase. In the ordinary way, the suspension formed by condensation, which we will refer to as a *condensed mist*, is the more finely-divided and, unless special steps are taken to control the condensation, most of the drops are of a diameter less than 0.01 mm. and few are larger than 0.02 mm. To achieve a majority of drops in this size range by mechanical dispersion, however, requires considerable expenditure of energy; and suspensions formed in this way, which we will refer to as *mechanical sprays*, do not usually contain many drops below 0.1 mm. in diameter. Unless specially controlled artificial methods of generation are employed, both condensed mists and mechanical sprays contain a wide variety of drop sizes.

Flammability of Condensed Mists

Suspensions consisting of mixtures of combustible liquids with air are in principle capable of propagating flame when ignited, even though the liquid is so involatile that no appreciable amount of vapor is formed at the ambient temperature. Haber and Wolff (*1*) showed that condensed mists involving combustible liquids exhibit a lower limit of flammability analogous to that of combustible gases

Table 1.—Lower Limits of Flammability in Air of Mists and Vapors Compared *Haber and Wolff (1)*

	Mists				Vapors	
	Temp.	Conc. (oz./cu.ft.)			Temp.	Limit
Liquid	° F.	Mist	Vapor	Total	° F.	(oz./cu.ft.)
Petroleum 356-428° F.	75	0.0261 ±0.0004	0.0179 ±0.0003	0.044 ±0.0007	140	0.043 ±0.0007
Tetralin	84	0.0409 ±0.001	0.001	0.0409 ±0.001	212	0.0416 ±0.0009
Quinoline	97	0.0662 ±0.0015	0.0015	0.0662 ±0.0015	230	0.064 ±0.0012

and vapors mixed with air. They concluded, in fact, that the lower limit concentration of the mist of a liquid is virtually the same as that of the same liquid wholly in the form of a vapor at the somewhat higher temperature necessary for vaporization.

Their determinations of flammability were made in a vessel in the form of a vertical cylinder, 3 in. in diameter and 20 in. high. At the instant of testing, the upper end of the cylinder was opened and the source of ignition was a 4 mm. gas flame applied at the lower end. The liquids used were: a petroleum fraction distilling from 356 to 428° F.; tetrahydronaphthalene (tetralin), b.p. 404° F.; and quinoline, b.p. 460° F. Of these, the petroleum fraction alone had an appreciable vapor pressure at the temperature of the mist, and in this case the concentration of vapor had to be taken into account in specifying the limits of the mist.

The results are summarized in Table 1, which illustrates the conclusions already stated.

Burgoyne and Richardson (*2*) later investigated the flammability of condensed mists of some commercial oils in connection with the possible explosion hazard arising from cutting oil mist formation in machine shops.

By this time it had become customary to measure limits of flammability in a long vertical tube with the flame proceeding upwards from an open towards a closed end. Under these conditions the flame progresses into an essentially quiescent mixture, since the expanded products of combustion are released freely at the open end.

Using these conditions with a 1.9 in. diameter tube, Burgoyne and Richardson obtained the lower limit values shown in Table 2, with an estimated error of about 10%. In all cases the liquids were insufficiently volatile to give appreciable vapor concentrations at the temperature of measurement (50-60° F.). The limit was raised in narrower tubes but propagation still took place in a 15/16 in. diameter tube. In quiescent mist however, flame would not pass through ⅛ in. mesh gauze. It was observed that at the lower limit concentration the opacity of the mist was high, and what appeared as quite a thick haze in the congested and under-ventilated machine shops of war-time represented in reality but a small fraction of the lowest flammable concentration.

The lower limit concentration of condensed lubricating oil mists was measured by Burgoyne, Newitt & Thomas (*3*) in connection with the problem of crankcase explosions. Such explosions are normally due to the ignition of mist formed by the contact of lubricating oil with some seriously overheated part of the engine. The overheated part itself usually becomes the source of ignition.

In this work a 2-inch diameter tube was used for flammability testing, but refinements of technique were introduced. Permanent gases, possibly formed by oil decomposition in the mist generator, were shown to be absent from the mist under test. The drop size distribution of the mist was ascertained, and the concentration of the mist measured at the limit of flammability was corrected to conditions of isokinetic sampling.

The lower limit for Shell Lubricating Oil Talpa 30 was found to be 0.049 ± 0.001 oz./cu. ft. and this figure was not affected appreciably by changes in drop size distribution occasioned by normal variations in the conditions of condensation.

Flammability of Mechanical Spray

Engine crankcases, during operation, contain a considerable quantity of suspended oil in the form of mechanical spray dispersed by the moving parts. In order to assess the possible part played by these larger drops in a crankcase explosion, Burgoyne and Cohen sought to examine the effect on the lower limit of flammability of drop size varied over a wide range. For this purpose they developed a generator for the production of condensed liquid-in-air suspensions in which the drop size is essentially uniform but capable of control (*4*). The method is a modification of one due to Sinclair and La Mer (Columbia University, New York) in which the saturated vapor is condensed under conditions of controlled cooling, in air containing a controlled number of condensation nuclei.

Table 2.—Lower Limits of Flammability in Air of Condensed Mists of Commercial Oils. *Burgoyne & Richardson (2)*

Oil	Lower limit (oz./cu.ft.)
Mineral cutting oil, No. 1 (closed flash-point: 266° F.)	0.042
Mineral cutting oil, No. 2 (closed flash-point: 293° F.)	0.056
Mineral cutting oil No. 2 after straight distillation (closed flash-point: 230° F.)	0.055
Mineral cutting Oil No. 3 (Shell M. 6)	0.049
Sperm quenching oil	0.046
Pool diesel oil	0.049

With this form of generator, it was necessary to use a liquid consisting of a single substance, and a study was made of the effect of drop size on the lower limit of flammability.

A 2-in. tube was used, with suspensions of pure tetralin (*5*), c.f. Haber & Wolff (*1*), see Table 1. The concentration of tetralin in air in a lower limit mixture was measured by suddenly enclosing the unburnt mixture in a known length of the flammability testing tube, and collecting therefrom, and weighing, the whole content of tetralin drops.

Table 3, Section A, shows figures taken from a smoothed curve (*5*) relating lower limit concentration with drop diameter and illustrates the trend of the results obtained. For drop diameter of 0.01 mm. and less, the lower limit concentration corresponds closely to that for tetralin vapor in air, measured at the slightly higher temperature necessary to achieve the requisite vapor pressure.

The investigation has now been continued by H. D. Taylor working in collaboration with the writer. As the result of a careful study of the effect of the controls on the operation of the generator, and with scrupulous attention to cleanliness, it has been possible to extend the range of the

monodisperse tetralin suspensions produced to drop diameters of above 0.1 mm. Measurements of the lower limit of flammability under the same conditions, and by the same methods as before, have yielded the results presented in Table 3, Section B. These continue the downward trend of the lower limit with increasing drop diameter previously found by Burgoyne and Cohen.

Significance of Concentration in Sedimenting Suspensions

The significance of *concentration* as used in the present context with reference to the larger-drop suspensions requires some consideration. Let C_v represent the concentration of drops in air measured as indicated above, i.e. the weight of drops momentarily present in unit volume of suspension. Further, let

V_a = downward flow velocity of the air;
V_f = upward velocity of flame through suspension;
V_s = sedimentation velocity of drops relative to the air.

Table 3.—Influence of Drop Diameter on Volume Concentration of Tetralin-air Suspensions at the Lower Limit of Flammability

Drop diam. (mm.)	Limit conc. (oz./cu.ft.)
Section A	
0.010	0.045
0.020	0.037
0.030	0.026
0.040	0.019
0.050	0.018
Section B	
0.077	0.012
0.087	0.0096
0.093	0.0079
0.099	0.0071
0.111	0.0060
0.115	0.0046
0.136	0.0029

Then, upward velocity of flame relative to air $= V_f + V_a$ and upward velocity of flame relative to drops $= V_f + V_a + V_s$. Hence the flame encounters liquid and air, in the ratio given not by C_v, but by

$$C_v \cdot \frac{V_f + V_a + V_s}{V_f + V_a} \qquad (1)$$

The concentration given by this expression we will call the *flame-front concentration*, and denote it generally by C_f. C_v we refer to as the *volume concentration*.

For small drops, C_f does not differ appreciably from C_v, because V_s is small compared with $V_f + V_a$. However, as the drop diameter increases above 0.01 mm., the difference becomes more significant. An approximate correction of the values of C_v, shown in Table 3, gives C_f values which show little variation with drop diameter. The question therefore arises as to whether the flame-front concentration at the lower limit of flammability may not in fact be independent of drop size.

Work is currently in progress to elucidate this point. A method of directly ascertaining the flame-front concentration in lower limit flames by the analysis of the flame products has been developed and applied to monodisperse suspensions of tetralin in air with drop diameters extended to more than 0.2 mm. The results are not yet complete, but they indicate that at the most there is only a small downward trend in limit flame-front concentration with increasing drop size.

Upper Limits of Flammability

So far, attention has been fixed upon the lower limit of flammability of mists and sprays. In practice this is the quantity that is usually of chief concern.

The position regarding upper limits is not altogether clear. Burgoyne and Richardson (*2*) gave some upper limit figures for commercial oil mists which suggested that the range of flammability is similar to that for hydrocarbon vapors. This seems a likely conclusion, but further consideration, supported by practical experience, shows that unless the suspension is completely uniform in concentration, flame propagation through the leaner parts may occur even though the average concentration is above the true upper limit. At such high liquid/air ratios, uniformity of concentration is most unlikely to prevail in practice and is difficult to accomplish under experimental conditions. Thus, partial flame propagation has been obtained experimentally in extremely dense suspensions, which were doubtless nonuniform. Precise upper limit values for mists and sprays are not known and appear to be of somewhat academic significance in any case.

Influence of Drop Size on Suppression of Flammability by Added Inert Gas

The progressive addition of incombustible gas to the air supporting a liquid drop suspension raises the lower limit of flammability, slowly at first, but with increasing rapidity later. Finally, at a certain proportion of added gas it becomes impossible to form a flammable suspension. Burgoyne, Newitt & Thomas (*3*) found that with a condensed lubricating oil mist (drop diameter mainly below 0.01 mm.) the requisite addition of carbon dioxide for suppression of flammability was 28.3 vol. % which is similar to the figures generally obtained for hydrocarbon vapors of various kinds (c.f. *6*). Burgoyne and Cohen (*5*) showed that with 0.010 mm. and smaller drops of tetralin, the limiting addition of nitrogen was about 40 vol. % which is again near to typical figures for hydrocarbon vapors generally (*6*). With larger drops however (up to 0.045 mm.) the requisite proportion of added nitrogen increased somewhat. H. D. Taylor has found that the limiting addition appears to pass a peak with increasing drop size. At 0.2 mm. it is appreciably below 40% and is continuing to decrease.

Influence of Drop Size on Burning Velocity

Burgoyne, Newitt & Thomas (*3*) measured the burning velocity of a condensed lubricating oil mist as a function of the oil-in-air concentration, using a burner method. They found that the maximum burning velocity was about 32 cm./sec., referred to the suspension at N.T.P. and that it was obtained with a mixture rather more rich than the stoichiometric.

Table 4.—Effect of Drop Size on the Burning Velocity of Monodisperse Tetralin-air Suspensions. *Burgoyne & Cohen (5)*

Drop diam. (mm.)	Flame-front conc. (oz./cu.ft.)	Burning velocity (cm./sec.)
0.008	0.067	28
0.009	0.062	31
0.010	0.087	39
0.011	0.084	42
0.015	0.069	59
0.017	0.061	62
0.022	0.064	55
0.029	0.060	68
0.030	0.060	67
0.034	0.045	58
0.034	0.052	57
0.038	0.048	58

Burgoyne and Cohen (*5*), also using burners, examined the effect of drop size on the burning velocity of monodisperse tetralin-air suspensions, and obtained the results shown in Table 4. In these experiments the *concentration* of the suspension was measured on the unignited mixture by means of a filter placed across the burner port. It was therefore the *flame-front concentration*, and it seems clear from Table 4 that the burning velocity increases somewhat with increasing drop size provided the concentration, expressed in these terms, is maintained constant. However, the mechanism of flame propagation undergoes transition with drop diameters above about 0.01 mm. and one result of this is that the reaction zone of the flame is greatly increased in thickness. That combustion is thus taking place at any moment in a much increased volume may be the reason why the flame is able to progress more quickly into the unburnt suspension as the drops become larger.

Explosions in a Closed Chamber

Burgoyne & Newitt (*6*) have reported experiments carried out by M. J. G. Wilson on the explosion of lubricating oil mists in a closed chamber of about 60 cu. ft. capacity. Some difficulty was experienced in designing a satisfactory mist generator for use on this scale and reproducible mists were not obtained. Over a number of experiments, however, the highest explosion pressure recorded was 113 lb./sq. in. which compares with a maximum of 122 lb./sq. in. for pentane vapor in the same vessel. In certain cases however the *rate* of pressure rise in a mist explosion was found to exceed quite appreciably that in a pentane vapor explosion. This was accounted for by the presence of acetylene and hydrogen in the suspension, which were formed by the cracking of oil in the generator. The laboratory generators used in the burning velocity measurements (*3*) gave no appreciable cracking, and the burning velocity was then similar to that for a hydrocarbon vapor. The larger-scale generator had a longer time of contact between oil and hot surfaces (possibly several seconds) and gave cracked products with the result described. This suggests that, in practice, prolonged contact with a hot surface, in the process of condensed mist formation, may produce similar results. An increase in the rate of pressure rise, without necessarily any increase in the maximum pressure attained, will render the explosion more difficult to relieve at an explosion vent or to stop at a flame trap.

Closed-vessel explosions involving sprays have not been studied. In view of the indication that burning velocity increases with drop size, it would be interesting to see if the rate of pressure rise in large-drop suspension explosions is correspondingly increased.

Conclusions

Flammable condensed mists, in which the drop diameters are mostly 0.01 mm. and less, propagate flame near the same limit as the corresponding vapor, as there is time for the drops to vaporize completely in the path of the advancing flame-front (*5*). Accordingly the lower limit of flammability, the requisite addition of inert gas for the suppression of flammability, and the burning velocity, are all those of the corresponding vapor. It is of value to note that when the lower limit concentration is expressed (as for a mist) in terms of weight of fuel per unit volume (or weight) of air, there is little variation as between different hydrocarbons excepting those of lowest molecular weight (*6*). So it seems possible to adopt a practical figure for all hydrocarbons and their mixtures which applies not only to vapors but to condensed mists as well.

Extinguishing additions of inert gas also vary little for hydrocarbon vapors in air (*6*) and here again a single figure which applies to all such vapors and mists for practical purposes seems possible.

When, however, a condensed mist is formed from the saturated vapor of a liquid hydrocarbon of high boiling-point, prolonged contact with the source of heat causing original vaporization may result by cracking in the formation of gaseous products of decomposition which do not share the combustion properties of the saturated hydrocarbons. Thus such presence of hydrogen or acetylene in the condensed mist will reduce its lower limit of flammability, raise the requirement of inert gas for flammability suppression, and increase the burning velocity.

The optical density of a hydrocarbon mist at the lower limit concentration of 0.045-0.050 oz./cu. ft. is very high and a 100-watt lamp is visible in it for only a matter of inches. Therefore light extinction methods are very convenient for the detection and measurement of flammable concentrations where the liquid giving rise to the mist has a negligible vapor pressure at the ambient temperature. It is in fact comparatively easy to design a photo-electric device that will give automatic warning at say 1 or 2% of the lowest flammable concentration.

For drop diameters above about 0.01 mm., the mechanism of flame propagation appears to change in that it is no longer possible for the drops to vaporize completely in advance of the flame front. Liquid drops therefore enter the flame and diffusion burning takes place. It appears however that if the concentration at the lower limit of flammability is expressed as the flame-front concentration and not as the volume concentration, drop size has rather little effect upon the limit value. The necessary addition of inert gas for extinction appears first to rise above the vapor value with increasing drop size and then to fall below it. It is presumed that there is a limiting drop size above which flame propagation becomes impossible, but this limit has not yet been located experimentally.

Flammable sprays of drop diameter 0.1 mm. or more arise in practice through mechanical dispersion. They are relatively transparent and optical methods of assessment are not suitable. The recent work on the lower flammability limit as a function of drop size has, nevertheless, focussed attention on the essential feature, which is the measurement of C_f, the flame-front concentration. Possible practical methods of making measurements on sprays from which this quantity can be computed and hence the flammability assessed, are the subject of present studies at Imperial College.

Acknowledgment

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FLAMMABILITY LIMITS of HYDROCARBONS at high temperatures and pressures

The recent widespread use of high temperatures and pressures in various manufacturing and mining processes has introduced hazards not associated with similar processes at lower temperatures and pressures. Gas mixtures that are ordinarily nonflammable often become explosive, "mild" gas-phase reactions become violent, and "stable" gas mixtures become spontaneously reactive at these elevated temperatures and pressures. Since the effects of temperature and pressure on the flammability characteristics of a combustible cannot at present be determined from basic principles, they must be determined experimentally. This necessitates the use of special limit-of-flammability and spontaneous-ignition temperature apparatus designed to work at initial pressures in excess of 10,000 lb./sq.in. The preparation of test mixtures, initiation of explosive reactions, and determination of explosion pressures pose special problems. Some of the apparatus used to date, results obtained, and special safety precautions that have been taken are discussed.

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The introduction of a number of new high-pressure and high-temperature processes in recent years has accelerated the development of equipment for use at the required elevated temperatures and pressures. Much of the equipment that was formerly in the "custom-built" category is now carried in stock by a number of manufacturers and suppliers. A recent summary of the available commercial equipment (*1*) and other articles that have appeared since World War II, as well as numerous inquiries received by the Bureau of Mines, indicate that determinations of the properties of many materials must be extended to higher temperatures and pressures. One such problem concerns the determination of the limits of flammability at elevated temperatures and pressures and the minimum spontaneous decomposition and ignition temperatures at elevated pressures of combustible gases and vapors.

For example, the use of compressed natural gas-air mixtures in the gas-injection method of oil recovery proved to be more hazardous than originally contemplated because of the increase in the upper limit of flammability of natural gas in air from about 14% at 0 lb./sq.in. gauge to 44% at 500 and 60% at 3,000 lb./sq.in. gauge (*2*). Similarly, the use of compressed-air blasting in coal mines necessitated a reevaluation of the possible hazards that would arise if mine gases were drawn into a 12,000 lb./sq.in. gauge compressor. As a part of this study, the lower limit of flammability of natural gas in air was found to decrease from 5% at 0 lb./sq.in. gauge to about 2.3% at 10,000 lb./sq.in. gauge (*3*). These data are presented graphically in Figure 1, which gives the limit of flammability of natural gas in air at about 28° C. and elevated pressure. In addition to these studies, the limits of flammability of a number of hydrocarbons and other combustibles have been determined at various elevated temperatures and pressures that were chosen to simulate a set of conditions encountered in practice (*4* to *10*).

These studies and others currently in progress have shown that the limits of flammability of most combustible-oxidant systems ordinarily become wider as either the temperature or the pressure is increased and so limit-of-flammability data obtained at ordinary temperatures and pressures cannot be applied in assessment of the potential hazards at elevated temperatures and pressures. Moreover, owing to the existence of cool flames at elevated temperatures, upper limits often increase drastically and unpredictably with a slight increase in temperature.

Limits of Flammability

The use of elevated temperatures and pressures in the manufacture, storage, transportation, and use of combustible gases and vapors has introduced explosion hazards which in many cases did not exist previously. For example, at moderately high temperatures the upper limits of flammability of combustibles such as pinane, the paraffin hydrocarbons, and some fuel blends are higher by a factor of 2 or more than the values predicted from data at room temperature. It is well, therefore, to determine the limits of flammability of a combustible-oxidant system at the temperatures and pressures of the particular process in which the system is to be used.

A glass apparatus is satisfactory for this purpose up to pressures of about 100 lb./sq.in. gauge and temperatures around 300° C. Use of a glass apparatus, or at least of a glass explosion chamber, makes it possible to observe directly whether flame propagates through any particular test mixture. Thick-walled glass pipes of various sizes are now available for this work, a 2-in. glass pipe having been used successfully in this connection for pressures up to 300 lb./sq.in. gauge. Operating personnel conducting these tests must be protected at all times from flying glass by a suitable barricade. In addition, it is advisable to wrap glass pipe with a transparent plastic gummed tape when possible.

Higher temperatures and pressures require a steel apparatus, pressure gauges to record the pressures developed during a test, pressure-relief devices to protect the equipment, ignition sources adequate to effect ignition in a flammable mixture, and gas-analysis apparatus to determine the extent of combustion following a test. Many of the precautions taken in the selection of an adequate apparatus for use at low temperatures and pressures are applicable here (*11*).

The procedure used to prepare a test mixture at elevated temperatures and pressures must be carefully evaluated before tests are conducted. Adequate mixing, a proper ignition source, and a typical postcombustion sample are necessary if the precision obtained at lower temperatures and pressures is to be maintained. The techniques used in this laboratory are discussed in many of the references listed below.

Minimum Spontaneous Decomposition and Ignition Temperatures

The use of elevated temperatures in a high-pressure process involving an unstable combustible or a combustible-oxidant system may prove hazardous owing to the decrease in ignition temperature that often occurs when the

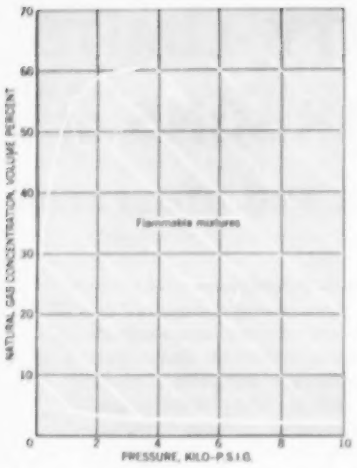

Fig. 1. Limits of flammability of natural gas in air at about 28° C. and elevated pressure.

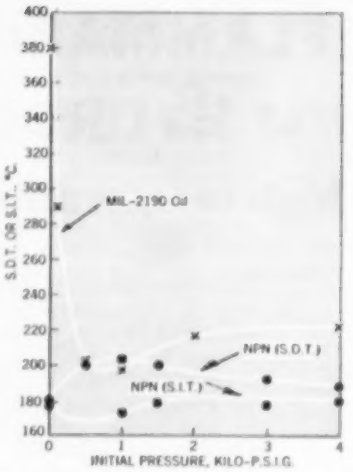

Fig. 2. Spontaneous-ignition temperature (S.I.T.) of MIL-2190 oil and spontaneous-ignition (S.I.T.) and decomposition (S.D.T.) temperatures of *n*-propyl nitrate (NPN) at elevated pressures.

system pressure is increased. The minimum spontaneous-ignition temperature (S.I.T.) of methane, for example, decreases from 537° C. at 0 lb./sq.in. gauge (*12*) to 240° C. at 9,000 lb./sq.in. gauge (*3*). The minimum spontaneous-ignition temperatures of a number of hydraulic fluids—petroleum-base as well as synthetic—drop to below 200° C. at pressures above approximately 500 lb./sq.in. gauge (*13*). The minimum S.I.T. of a typical hydraulic fluid (MIL-2190 oil) is plotted as a function of pressure in Figure 2. It is interesting to note that in this case the S.I.T. reaches a minimum value near 1,000 lb./sq.in. gauge and then increases with the pressure. This effect is not accidental, for an oil-vapor–air mixture can be kept at pressures above 1,000 lb./sq.in. gauge and temperatures between the minimum S.I.T. attained near 1,000 lb./sq. in. gauge and those along the S.I.T. curve without an explosive oxidation reaction; however, if the pressure is decreased slowly so that the S.I.T. curve is intersected, an explosive oxidation reaction occurs. A similar effect has been observed with a number of other combustibles. (See also *n*-propyl nitrate spontaneous-ignition temperature curve in Figure 2.) Materials such as acetylene (*14*) and ammonium nitrate (*15*) decompose spontaneously in the absence of air at moderately high temperatures and pressures; therefore, the decomposition and ignition characteristics of a combustible should be determined at the pressure to which it is to be subjected before any large-scale work is initiated. An example of this type of reaction is given in Figure 2 where the minimum spontaneous-decomposition temperature (S.D.T.) of *n*-propyl nitrate in nitrogen is plotted against pressure. For comparison, the S.I.T. of *n*-propyl nitrate in air is given as a function of pressure in the same figure. These data were obtained in a 425-cc. stainless steel test chamber heated with a modified crucible furnace, all tests being conducted behind a barricade.

Another point to be noted in connection with this work is that the vapors from combustible fluids used in systems operating above approximately 100 lb./sq.in. gauge pressure may ignite in air when projected against a surface heated to temperatures below the minimum spontaneous-ignition temperature of the combustible in air (*13*). A number of hydraulic fluids exhibit this property. Minimum spontaneous-ignition temperatures against Diesel injector pressures of two such fluids (MLO-54-581 and MLO-8200) in air and in contact with a Pyrex surface at 1-atm. pressure are given in Figure 3. Similar plots for two other fluids (MLO-53-446 and MIL-0-5606) show that their ignition temperatures are independent of injector pressure when the fluids are projected against Pyrex surfaces. The nature and composition of the heated surface affects these results (*12*). There are indications that this effect may be due to partial conversion of the spray-stream energy into heat.

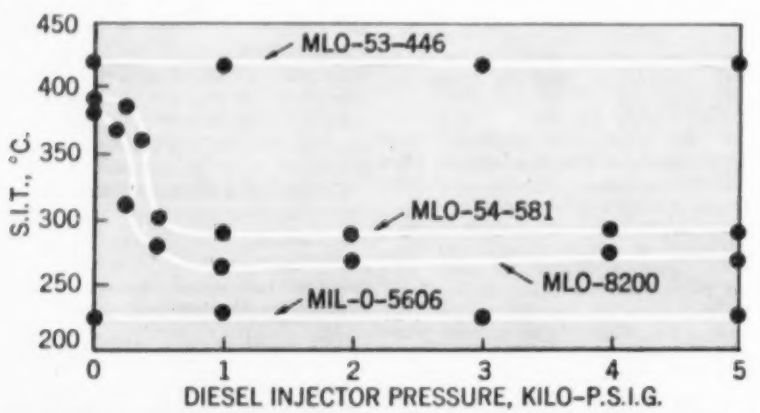

Fig. 3. Minimum spontaneous ignition temperatures (S.I.T.) of four hydraulic fluids in contact with a pyrex surface in air at one atmosphere pressure as a function of diesel injection pressure.

Acknowledgment

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design of PERFORATED PLATE FRACTIONATING TOWERS

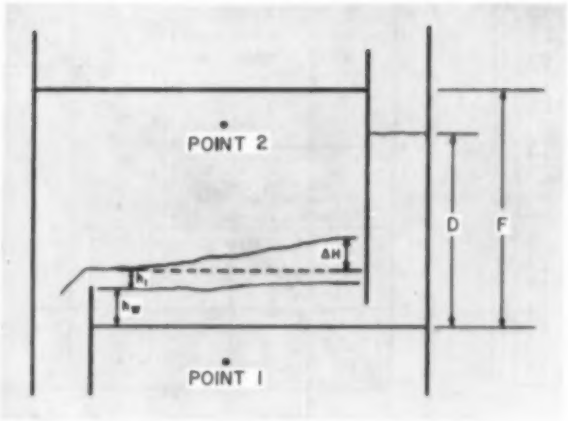

Fig. 1. Hydraulic relationships on a perforated plate.

A revival of interest in the use of perforated-plate fractionating towers has been due largely to the work of Mayfield and co-workers. This paper extends their work on design and applies information available in recent literature. Correlations have been developed which accurately predict dry and wet pressure drop. Other correlations permit the estimation of the hydraulic gradient and the stability with reasonable accuracy. These correlations should enable the engineer to design perforated-plate fractionating towers with the same confidence that he does bubble-cap towers.

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Perforated-plate fractionating towers were one of the first types used for vapor-liquid contact, but they were not widely used until recently, probably because of poor performance in the early thirties resulting from poor design. There has been a revival of interest in perforated plates in the past five to eight years, as is evidenced by the many recent articles on this subject. Information on pressure drop, stability, and plate efficiency for commercial-sized installations presented by Mayfield *et al.* (*21*) was used as a basis for design of over sixty perforated-plate fractionating towers by the Celanese Corporation up to the time of Mayfield's publication. There have been other valuable contributions by Arnold *et al.* (*1*), Hucks and Thomson (*10*), Jones and Pyle (*13*), Kamei and co-workers (*15* to *19*), Zenz (*25*), Hutchinson *et al.* (*12*), Hunt *et al.* (*11*), and Eld (*5, 6, 7*).

The purpose of this paper is to combine the results of these authors and to give improved methods for estimating the dry pressure drop, wet pressure drop, hydraulic gradient, and stability characteristics of the plate. Predicted values are compared with those reported in the literature. This paper is concerned only with those perforated plates in which only vapor passes through the holes and the liquid travels from plate to plate via downcomers.

Over-all Criteria for Design of Fractionating Towers

The design of perforated-plate fractionating towers requires consideration of the following factors.

1. *Number of actual plates.* The number of theoretical plates must be calculated and the plate efficiency estimated. The optimum liquid and vapor flows must also be determined.

2. *Tower diameter and plate spacing.* There should be sufficient disengaging space above each plate to prevent the carryover of liquid from one plate to another. The principal concern is the splashing of froth on the plate by the violent action of the vapor passing through the liquid.

3. *Pressure drop.* The pressure drop across the plate for a perforated plate requires the setting of the hole size, distance between the holes, weir height, and downcomer area and location. The pressure drop across the plate should be low enough to permit the liquid to flow from plate to plate, or, conversely, there should be sufficient elevation between plates to overcome the pressure drop across the plate.

4. *Stability of the plate.* Intimate contact between vapor and liquid is required, with no liquid passing through the holes and vapor passing through all the holes in as uniform a manner as possible.

The principal concern of this paper is the determination of items 3 and 4, which are discussed later in greater detail. These design features are specific to perforated-plate towers.

Pressure Drop

The hydraulic relationships on a perforated plate are shown in Figure 1. For satisfactory operation of the plate, the liquid level in the downcomer D must be less than the distance between the plates, $F + h_w$. Usually good design calls for the calculated D for clear liquid to be 50 to 60% of F, to allow for aeration in the downcomer.

The general method of calculation,

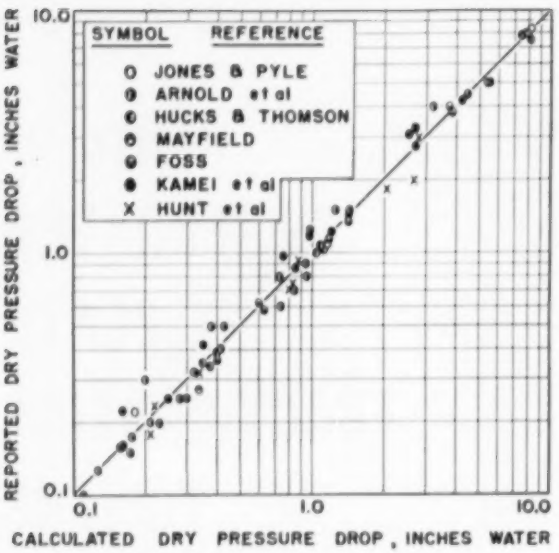

Fig. 3. Comparison of calculated and reported dry pressure drop through holes.

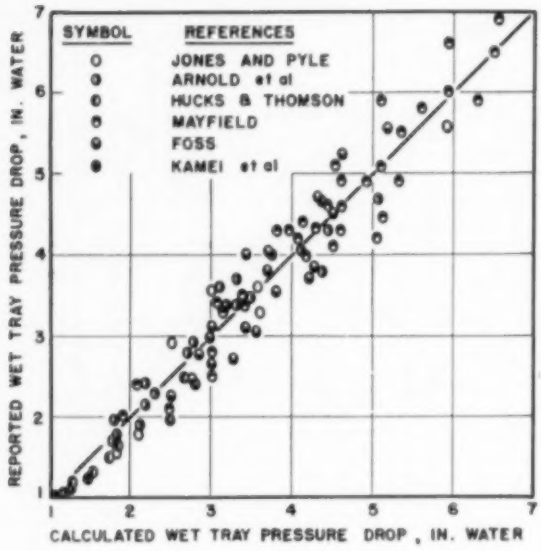

Fig. 5. Comparison of calculated and reported wet tray pressure drop.

D, is straightforward and is given in most standard texts. These show that D is equal to

$$\Delta P_w + h_1 + h_w + h_2 + \Delta H$$

PRESSURE DROP FROM POINT 1 TO POINT 2

The pressure drop from point 1 to point 2 (Figure 1) is called the *wet pressure drop* and is equal to the sum of

1. Dry pressure drop through the hole
2. Hydrostatic head above the hole
3. Head to form bubbles and to force the bubbles through the liquid.

The dry pressure drop and the hydrostatic head can be estimated with fair reliability. There is no available method for estimating the head to form bubbles and to force the bubbles through the liquid but, fortunately, this head is small. Therefore, the wet pressure drop was estimated from the dry pressure drop and an effective head, which combines the hydrostatic head above the hole and the head to form the bubbles and to force the bubbles through the liquid.

The *dry pressure drop* is that pressure drop that would occur if the vapor passed through the holes without liquid on the plate. The dry pressure drop can be calculated by the orifice equation

$$\Delta P_D = \frac{0.003\ F_S^2(1-\beta^2)}{C^2}$$

The orifice coefficient, C, is a function of the thickness of the plate, the Reynolds number, and the care in drilling or punching the holes. Available data indicate that the most important variable is the thickness of the plate. Figure 2 shows the variation of C with the ratio of the thickness of the plate and the diameter of the hole. This figure shows that the smaller the ratio and thus the thickness of the plate, the greater the value of C. This is consistent with the fact that a nozzle has a large coefficient and a thin-edge orifice a small one. This curve holds only if the holes are drilled or punched clean and all the burrs removed.

Dry pressure drops have been measured by several investigators. A comparison between the reported and calculated pressure drops appears in Figure 3, which shows that 90% of the points have a deviation of less than 20% and that the average deviation is about 10% for all the points.

The *effective head* is the hydrostatic head plus the head to form the bubbles and to force the bubbles through the vapor. An empirical correlation was developed to predict this effective head. This correlation, which is shown in Figure 4, plots effective head as a function of total submergence. Total submergence, h_e, is the sum of

1. Weir height
2. Height over weir-weir crest
3. One half of hydraulic gradient.

The *wet pressure drop* is then the sum of the dry pressure drop plus the effective head. Figure 5 shows a comparison of wet pressure drops calculated by the foregoing method with those measured by several investigators. This figure shows that for an air-water system, 90% of the points have a deviation from the measured of less than 15%. The method will give conservative answers for most other systems. Hunt *et al.* (*11*) showed that the wet pressure drop for systems with low surface tension was usually lower than for the air-water system. The maximum difference shown was only 0.3 in. of water, and this is within the accuracy of the proposed correlation.

HYDRAULIC GRADIENT

The hydraulic gradient is the head required at the inlet weir to cause liquid flow across the plate. Many writers have indicated that the hydraulic gradient for perforated plates is small; however, the only experimental data reported, by Hucks and Thomson (*10*) and Hutchinson *et al.* (*12*), showed that for some conditions the hydraulic gradient can be appreciable. These data indicate that the designer should consider this factor in plate design.

The method of correlation for perforated plates was based on the correlation of Klein (*20*) for bubble-cap plates. Klein considered the flow across the plate similar to flow in an open channel and correlated friction factor against a Reynolds number. The properties for the friction factor and Reynolds number were those of the froth flowing across the plate. In addition, Klein applied a correction to the friction factor which was based on the height of the clear liquid on the plate. Klein's method gave good agreement with the available data on hydraulic gradient for bubble cap plates. Hucks and Thomson used this type of correlation for their data on perforated plates; however, their method did not correlate all the data.

The friction factor is defined as

$$f = \frac{gR_H\Delta H}{12V^2L}$$

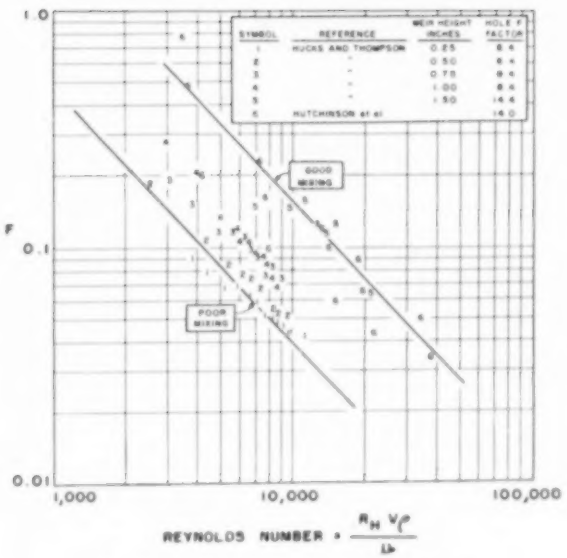

Fig. 6. Friction factor plot for hydraulic gradient.

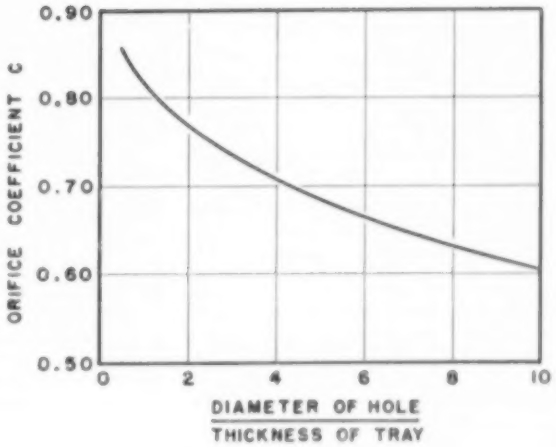

Fig. 2. Orifice coefficient.

where

$$R_H = \frac{bL_o}{b + 2\ L_o},\ \text{ft.}$$

$$L_o = \frac{2(h_w + h_1 + 0.5\ \Delta H)}{12}$$

$$V = \frac{Q}{60 \times 7.48 \times L_o \times \phi}$$

The Reynolds number is

$$Re = \frac{R_H V \rho_L}{\mu}$$

This is the Reynolds number of the foam since the factor to correct the density and viscosity of the clear liquid is the same and cancels out.

The friction factor for hydraulic gradient on perforated plates, presented in Figure 6, shows the data of Hucks and Thomson and Hutchinson *et al.* There is considerable spread in the data, as indicated by the line limits. In general, the higher the weir height and the greater the F_s, the greater the friction factor. The reason for the effect of these variables cannot be definitely established. However, one explanation is that both the weir height and the F_s factor affect the mixing characteristics of the plate. The higher the weir height and the greater the F_s, the more complete the mixing on the tray. The greater the mixing, the greater the liquid flow through the channel at any time. The greater the liquid flow, the greater the pressure drop. The method given above assumes no mixing. Thus, mixing will give a greater friction factor for the same Reynolds number.

Another analysis of the hydraulic gradient problem is given in Appendix I. This further supports the concept of increased gradient with increasing mixing on the plate.

As with bubble-cap plates, the hydraulic gradient for perforated plates is usually not large enough to affect plate stability. However (as with bubble-cap plates), there are conditions when the hydraulic gradient could be large enough to result in unstable plate operation. Such a set of conditions might result when the length of liquid path is long and the weir height and F_s factor are high. This would result in a high gradient and the plate will weep liquid at the inlet weir if the vapor velocity is not large enough to offset this high gradient. To avoid this weeping, the hydraulic gradient should be less than 50% of the dry pressure drop through the hole.

HEIGHT OVER WEIR

The height of liquid over the overflow weir can be calculated for a straight rectangular weir by the Francis formula with correction end effects for a segmental weir. The method of calculation is given in standard texts.

PRESSURE DROP FROM DOWNCOMER

The head of liquid required to overcome the pressure drop from the downcomer onto the tray can be calculated from the following equation from Cicalese *et al.* (*3*):

$$h_2 = 0.56\left(\frac{Qb}{449\ A_o}\right)^2$$

Plate Stability

For efficient plate operation, intimate contact between vapor and liquid is required. This means that there must be sufficient vapor velocity through the holes to prevent liquid from weeping through the holes but that the vapor velocity is not too great to cause excessive pressure drop across the plate.

MINIMUM VAPOR VELOCITY

There is a minimum vapor velocity for each set of conditions that will prevent liquid from weeping through the holes. Some of the factors that affect weeping are:

1. Pressure drop through dry hole. There is a relationship between the pressure drop through a slot in a bubble-cap and for a hole in a perforated plate. In a bubble-cap the opening in the slot is equal to the pressure drop through the slot. This relationship holds because the pressure of the liquid on the plate must balance the pressure drop through the hole and

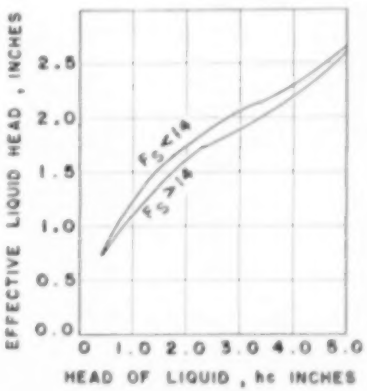

Fig. 4. Effective liquid head.

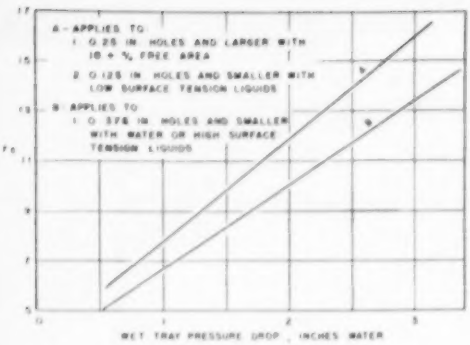
A - APPLIES TO
1 0.25 IN HOLES AND LARGER WITH
10 + % FREE AREA
2 0.125 IN HOLES AND SMALLER WITH
LOW SURFACE TENSION LIQUIDS
B APPLIES TO
1 0.375 IN HOLES AND SMALLER
WITH WATER OR HIGH SURFACE
TENSION LIQUIDS
WET TRAY PRESSURE DROP, INCHES WATER

Fig. 7. Weeping correlation.

the remaining liquid head. One could hypothesize that a similar relationship holds in the perforated plate. Imagine a hole covered with liquid but on which there is no downward force of the liquid head. In this hypothetical condition, at low vapor velocities, liquid would fall through the hole. As the vapor velocity was increased, the amount of liquid that wept would decrease until it stopped. Extrapolation of weeping data to zero liquid head gives the dry-plate pressure drop to prevent weeping approximately equal to hole diameter.

2. Height of liquid above hole. With a liquid head above the hole, the head has a tendency to force the liquid down the inside of the hole. The higher the head the greater the force. This force must be overcome by putting more vapor through the hole.

3. Surface tension of liquid. It is known that with small holes, high surface tension, and a low head, liquid will not weep through the holes even with zero vapor velocity. Even with holes ⅛-in. in diameter there is resistance to weeping by the surface-tension effect.

4. Action of vapor and liquid on plate. The wet pressure drop is a function of these items. Therefore, an empirical correlation was developed which expressed the minimum vapor velocity required to prevent weeping as a function of wet pressure drop. This is shown in Figure 7, where the vapor velocity is expressed as F_s.

A comparison between the calculated minimum F_s from Figure 7 and that minimum F_s reported by several investigators is given in Figure 8. This figure shows that 90% of the points have a deviation from the reported of less than 30%. This figure also shows considerable scattering of the points, but this is to be expected since the measurement of the weeping is difficult. It is not serious in most cases as it is possible to design above the minimum without interfering with the flexibility of the tower. For towers where pressure drop is important, however, such as a vacuum tower, the wide scattering of the data introduces problems in design.

Figure 7 can be used with confidence only for hole sizes of 0.387 in. and less; however, this does not preclude the use of larger diameter holes. Hunt *et al.* (*11*) showed that 0.5-in. holes could be operated without weeping. Except for the special case of fouling of the plates, however, the authors believe that 3/16-in. holes give the most satisfactory design.

It should be noted that experiments with methyl alcohol and air gave as good a correlation as did those with the water-air system.

MAXIMUM HOLE VAPOR VELOCITY

The velocity through the holes is limited by the pressure drop across the plate, which means that the velocity through the hole must be such that the pressure drop through the hole plus the other pressure drops in the system is less than the clear liquid level in the downcomers.

There has been concern that too high hole vapor velocity would result in excess liquid carryover. Hunt *et al.* showed that entrainment for the same tower vapor velocity was not a function of hole vapor velocity. They concluded that liquid carryover was a function then of tower vapor velocity.

Design Procedure

The basic purpose of this paper is to present correlations for predicting dry pressure drop, wet pressure drop, and weeping characteristics of a perforated plate tower. These, of course, are only a part of the correlation necessary for the complete design of a fractionating tower and many of these other correlations have been adequately covered in the literature. In order to show how the correlations of this paper tie in with the other correlations, a general design procedure is summarized below.

1. Number of theoretical plates. The determination of the number of theoretical plates in a perforated-plate tower is the same as for the conventional bubble-cap tower. This is treated adequately in many standard references.

2. Plate efficiency. This has been the subject of much attention in the last several years and is an area in which there is considerable difference of opinion.

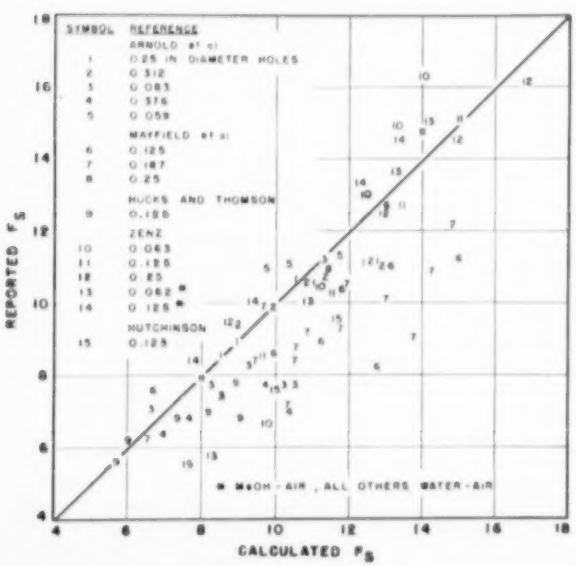

Fig. 9. Friction factor plot for hydraulic gradient.

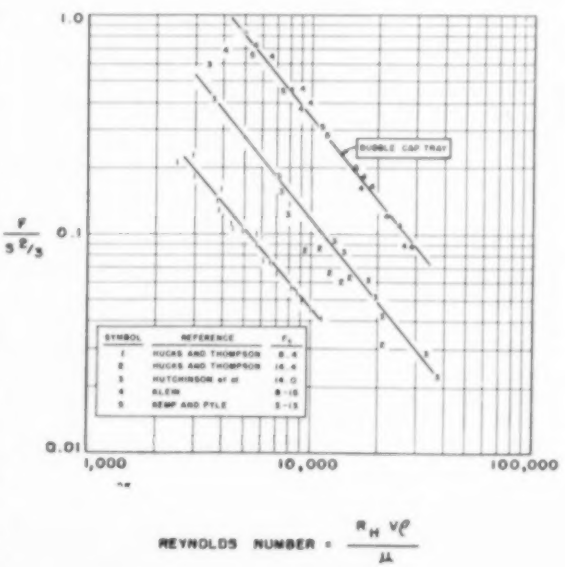
BUBBLE CAP TRAY
SYMBOL REFERENCE F_s
1 HUCKS AND THOMPSON 8-6
2 HUCKS AND THOMPSON 10-6
3 HUTCHINSON et al 10-0
4 KLEIN 8-15
5 KEMP AND PYLE 5-15
$\frac{F}{S^{2/3}}$
REYNOLDS NUMBER = $\frac{R_H V \rho}{\mu}$

Fig. 8. Comparison of calculated F_s for weeping with measured F_s.

A complete evaluation of the problems associated with estimating plate efficiency is beyond the scope of this paper. However, two methods which have been used with reasonable success will be mentioned.

One method, that of Gerster, is presented in the "Third Annual Progress Report of the American Institute of Chemical Engineers" (*9*) and in a paper given at the Fourth World Petroleum Congress (*4*). Gerster showed that this method checked reported efficiencies of Mayfield (*21*) for the *n*-propanol–sec-butanol system. Rush and Stirba (*23*) obtained fair agreement in checking experimental efficiencies in an 18-in. sieve-plate tower with acetic acid–water and methyl isobutyl ketone–water systems. The empirical method of one of the present authors (*22*) may be used to estimate plate efficiency. This correlation also gave excellent agreement for the data of Mayfield.

3. Tower diameter. The estimation of tower diameter and plate spacing for perforated-plate towers will follow the same basic principles as for the design of bubble-cap plates. There has been a considerable amount of study of this problem in the past several years although most of it has been directed toward bubble-cap plates. Again, it is not the purpose of this paper to give a complete review of this problem.

The passage of vapor through the holes in the plate results in the formation of a froth on the plate. It has been shown that the height of this froth increases with increasing F factor and that when the froth approaches the plate above, there is excessive carryover of liquid. This high carryover results in reduced plate efficiency and, most important, flooding of the tower.

The classical method of estimating tower diameter is that of Brown and Souders (*2*). The method gives conservative answers, and for close design tower area may be reduced by 20 to 50% over that given by the Brown-Souders method. The authors feel, however, that although the Brown-Souders method is conservative, it is a good design criterion in that it permits adequate flexibility in tower operation.

The tower diameter is also a function of plate spacing, and the optimum plate spacing is a matter of economic balance. This procedure has been adequately treated in standard references. Usually the optimum plate spacing is from 18 to 24 in.

4. Downcomer area. The downcomers should be sized so that the liquid velocity is about 0.3 ft./sec. for nonfoaming liquids. If the liquid (such as absorber oil), foams, the liquid velocity may have to be as low as 0.1 ft./sec.

5. Hole size. Mayfield *et al.* have recommended 3/16-in. holes for commercial use. The authors agree with this recommendation; however, for designs near the weep point, such as in vacuum towers, they recommend that ¼-in. holes be used. The correlation of Figure 7 is more conservative for smaller holes.

6. Minimum hole velocity. The minimum hole velocity is determined by trial and error. A value of F_s is assumed and the wet pressure drop calculated. A satisfactory solution is reached when the assumed value of F_s is slightly greater than that predicted by Figure 7.

7. Maximum hole velocity. The maximum hole velocity is that which will give a liquid buildup in the downcomer which is about 50% of the available height in the downcomer. The method of calculation is given in the section on pressure drop.

8. Design hole vapor velocity. The exact design depends on the degree of flexibility desired; the authors suggest that a good design is halfway between maximum and minimum.

9. Hole spacing. The distance between the holes should be between three to five times hole diameter. Hunt *et al.* showed that spacing less than this increased the tendency of the plate to weep.

10. Effect of weir height on pressure drop through the plate, the hydraulic gradient and the plate efficiency. The higher the weir, the higher the pressure drop and the hydraulic gradient. On the other hand, higher weir heights in some cases increase plate efficiency. The selection of weir height is then an economic balance among the foregoing variables.

For small diameter columns, 12 in. or less, a splash baffle should be installed ahead of the outlet weir.

11. Design of inlet weir to give good liquid distribution on the plate and to provide a liquid seal on the downcomer for startup. Mayfield *et al.* observed that when the liquid spilled onto the plate there was enough vertical impact to cause weepage when there were holes close to the inlet weir. They mentioned that this can be prevented by placing the first row of holes at least 4 to 8 in. from the inlet weir. They also pointed out that a recessed inlet weir will permit perforations within 2 to 4 in. of the weir.

Conclusions

A design method for perforated-tray fractionating towers based on information available in the literature has been proposed. In the development of this design method, correlations have been developed or extended for

1. Dry pressure drop
2. Wet pressure drop
3. Hydraulic gradient
4. Weeping on the plate

Most of the information was developed for the water-air system (there were some data available for weeping for the methyl alcohol-air system) and therefore has limitations; however, the similar correlations for bubble-cap plates were based on the water-air system and have given good results. Additional work on other systems would strengthen these correlations. The methods given permit the design of perforated-plate fractionating towers with the same accuracy as of bubble-cap towers.

Appendix 1

The section on hydraulic gradient presented a correlation of friction factor, f, as a function of Reynolds number. There was considerable spread in the data, which was attributable to difference in mixing on the plate.

Klein in his work on bubble-cap plates was able to correlate all the available data by correcting the friction factor for the height of liquid on the tray. A modification of this concept was used in Figure 9, where the term $f/S^{2.5}$ was correlated as a function of Reynolds number. Two curves were obtained for the perforated plates. The lower curve represents the data of Hucks and Thomson, the second curve the data of Hutchinson *et al.*, and the third curve was for the bubble cap data of Klein.

The first impression from analysis of these data is that the data of Hutchinson are in error. The Hutchinson data for perforated plates approach those of the bubble cap plates and this at first is hard to reconcile. The data for Hutchinson *et al.* were plotted with hydraulic gradient as a function of height of clear liquid, h_c, for liquid flow rates of 35 and 50 gal./min. As would be expected, the hydraulic gradient at constant liquid rate decreases with increased h_c. An extension of the line through the Hutchinson data gives good agreement with the Hucks and Thomson data for the same conditions, namely, length of bubbling path = 2.5 ft. and $F_s \geq 14$. This indicates that the data are consistent and that the difference in the curves on Figure 9 is real and that therefore there are other factors besides the height of liquid on the tray that affect hydraulic gradient.

This conclusion would support the recommended correlation, Figure 6, where the difference in the curves was attributed to different mixing characteristics on the tray.

Appendix 2

Following is an example of the design factors specific to a perforated plate.

TOWER DESIGN CONDITIONS

Liquid rate = 100 gal./min.
Liquid density = 56 lb./cu.ft.
Liquid viscosity = 0.3 cp.
Vapor rate = 30,000 lb./hr.
Vapor density = 0.15 lb./cu.ft.

Tower Diameter

A tower diameter of 5.5 ft. is calculated from the Brown-Souders method for a plate spacing of 18 in.

Downcomer Area

Downcomer area of 0.75 sq.ft. is calculated for a downcomer liquid velocity of 0.3 ft./sec. This area requires a weir length of about 50 in. for a cross-flow plate.

Hole Size

A plate with a thickness of 12 gauge and 3/16-in. holes is assumed on a ¼-in. triangular spacing.

Minimum Hole Velocity

An $F_s = 10$ and a 2-in. submergence are assumed, and calculations are as follows:

1. *Dry-plate Pressure Drop*

$$\frac{\text{diameter of hole}}{\text{thickness of tray}} = \frac{0.1875}{0.109} = 1.72$$

From Figure 2 the orifice coefficient $C = 0.77$

$$\Delta P_p = \frac{0.003 F_s^2 (1 - \beta^2)}{C^2}$$

For 3/16-in.-diam. holes on ¼-in. spacing, $\beta = 0.056$ and ΔP_p is calculated to be 0.5-in. water.

2. *Effective Liquid Head*

From Figure 4 for a 2-in. submergence and $F_s = 14$, the effective head = 1.7 in. liquid or 1.5 in. water.

3. *Total Pressure Drop*

The sum of the dry-tray pressure drop and the effective liquid head = 2 in. water.

4. *Stability*

From Figure 7 for a 2.0 in. pressure drop the minimum F_s is 12.

Calculations 1 through 4 are then repeated with an assumed F_s of 13. A total pressure drop of 2.3 in. water is calculated which corresponds to an F_s of 13 on the stability curve. This is then the minimum hole velocity.

Maximum Hole Velocity

An F_s of 20 is assumed and a total pressure drop of 3.6 in. water calculated. This corresponds to a backup in the downcomer of about 6 in. liquid. By trial and error an F_s of 35 is found to have a backup in the downcomer of 9 in. liquid, which is one-half the plate spacing. This is then the maximum hole velocity.

Design hole Velocity

This is the average of the minimum and maximum velocities and is equal to F_s of 24. At this condition the total pressure drop is about 5 in. liquid and the backdrop in the downcomer is about 7 in.

Hydraulic Gradient

$$Re = \frac{R_H V \rho_L}{\mu}$$

$$R_H = \frac{bL_e}{b + 2L_e}$$

$$b = \frac{5.5 + 4.1}{2} = 4.8 \text{ ft.}$$

$$L_e = 2 \times 2 = 4 \text{ in. or } 0.333 \text{ ft.}$$

$$R_H = 0.293 \text{ ft.}$$

$$V = \frac{Q}{60 \times 7.48 \times L_e \times 0.333}$$

$$Q = \frac{100}{4.8} = 21 \text{ (gal.)(min.)/ft. plate}$$

$V = 0.42$ ft./sec.

$Re = 34{,}000$ and from Figure 6, f is about 0.04

$$\Delta H = \frac{12 f V^2 L}{g R_H}$$

$\Delta H = 0.04$ in. liquid, which is less than 50% of the calculated dry pressure drop. Therefore, the plate is stable.

Weir Height

$$\text{Submergence} = 2 \text{ in.} = h_w + h_i + 0.5\Delta H$$

From the Francis formula for 24 gal./(min.)(ft.) weir length, $h_i = 0.75$ in. Therefore, a weir height of 1¼ in. is required for a 2-in. submergence. This weir height appears to be satisfactory because it gives a low hydraulic gradient and low pressure drop. A lower weir height would appreciably increase the hydraulic gradient.

Notation

- A_o = smallest flow area at bottom of downcomer, sq.ft.
- β = fraction-free area of active plate
- b = width of plate, ft. (for circular plates, this is the average width between tower diameter and weir length)
- C = orifice coefficient
- f = friction factor
- $F_s = u\sqrt{\rho_v}$
- g = gravitational constant, 32 lb.-mass ft./lb.-force (sec.)(sec.)
- H = effective head on plate, ft.
- h_i = crest height over weir, in.
- h_s = pressure drop due to liquid flowing from downcomer onto plate
- h_t = total submergence = $h_w + h_i + 0.5\Delta H$, in.
- h_w = weir height, in.
- ΔH = hydraulic gradient, in.
- L = length of bubbling path, ft.
- L_e = foam height, ft.
- L_w = effective length of weir, in.
- ΔP_p = dry-plate pressure drop, in.
- ΔP_s = pressure drop over plate, in.
- Q = flow of clear liquid, (gal.)(min.)/ft. of plate width
- Re = Reynolds number
- R_H = hydraulic radius, ft.
- S = seal = h_s for perforated plate = h_s — height of slots above top of plate for bubble-cap plate
- u = vapor velocity in holes, ft./sec.
- V = velocity of foam, ft./sec.
- ϕ = foam density
- ρ_L = density of clear liquid, lb./cu.ft.
- ρ_v = vapor density, lb./cu.ft.
- μ = viscosity of clear liquid, lb./(ft.)(sec.)

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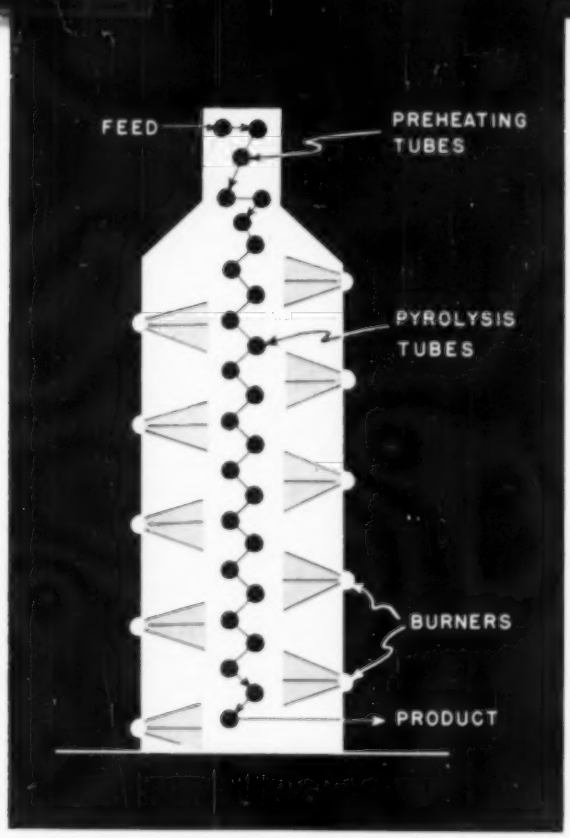

Fig. 1. Schematic diagram of thermal cracking furnace.

DESIGN of an ETHANE PYROLYSIS REACTOR

An improved method of design of a tubular reactor for the production of ethylene from ethane has been demonstrated. Product distributions for ethane pyrolysis were correlated by means of seven apparent over-all reactions together with rate expressions of empirical form. The Myers and Watson method of calculation was adapted for automatic computer use. As rigorous methods of thermodynamics and pressure-drop calculations were used, the range of operating conditions for which the results are applicable is limited only by the range of conditions of the pyrolysis experiments on which the kinetic correlations are based. Design parameters such as the heat-flux pattern were established by means of empirical rules, which experience has shown assure long periods of reactor operation without excessive coke formation.

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H. C. Schutt | Consultant, Boston, Massachusetts

The pyrolysis of ethane and propane recovered from refinery or natural gases constitutes the major source of ethylene, a useful base compound for the synthesis of organic chemicals. This paper presents improvements in the calculation method used in the design of reactors for this process. Recent advances in the technology for the prevention of coke formation in reactors are also discussed, and these results are illustrated by a sample calculation.

The cracking of ethane or propane at elevated temperatures as employed in commercial pyrolysis proceeds probably through a free radical mechanism in preference to the straight molecular process of dehydrogenation. The formation of methane from ethane and of the higher molecular weight by-products can also best be explained by reactions involving free radicals, as Kinney and Crowley (*3*) and various other investigators have proposed. All these theories, however, are somewhat speculative, and very little quantitative data are available on the free radical concentrations and the rates of the various reactions which actually occur. Therefore, in the design of a reactor or pyrolysis coil, summary molecular-reaction mechanisms are postulated and rates of reaction expressed on this basis.

A method of design of reactors for this process was described by Myers and Watson, (*6*) who used apparent over-all reactions to express empirically the kinetics of the pyrolysis. When the result is combined with relations from thermodynamics, heat transfer, and fluid flow theory, it is possible to perform a trial-and-error integration step by step along the length of a reactor coil by computing the local temperature, pressure, gas expansion, product distribution, and dimensions of the reactor tubes.

There are three reasons why the Myers and Watson method was not

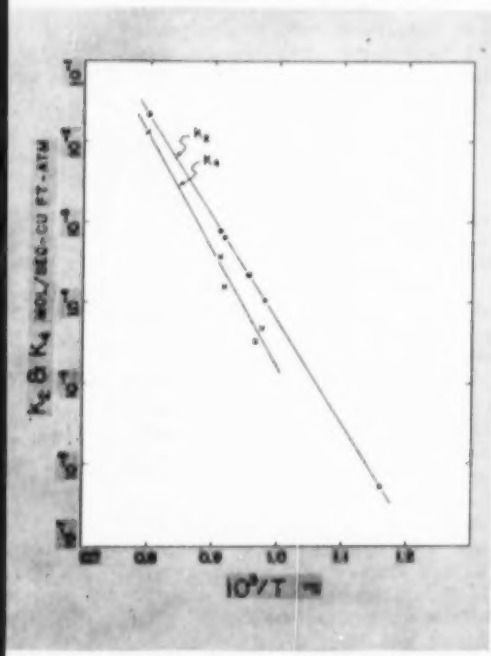
adopted by designers of commercial reactors. First, the calculations are so laborious that a simplified method was desired. It has been found that about 3 man-weeks is required to perform a single design integration. Second, the necessary apparent reactions must be derived from pyrolysis data. Myers and Watson presented apparent reactions for propane pyrolysis only, and owing to a lack of published data these apparent reactions were chosen in part on a speculative basis. It was not known whether the calculated product distributions would agree with experiment. Third, the sample design integration performed to demonstrate the use of apparent over-all reactions was unconvincing because an unrealistic heat-flux pattern that would have resulted in excessive coking was used.

A simplified method of calculation was described by Schutt (*9*), who also employed a step-by-step trial-and-error integration, but based it on empirically established product distributions and a general kinetic relationship expressing the reaction rate in terms of the disappearance of the key constituent of the feed. Because the products of secondary reactions are determined empirically, other quantities needed in the design integration such as heat requirement and gas expansion are not computed from thermodynamics and stoichiometry as in Myers and Watson's work, but are based on data obtained in operating similar reactors. A drawback of this procedure is that it does not provide a firm basis for investigating the effect of varying design conditions, as the experimental data must be for a reactor operating under similar conditions. On the other hand, by the method of Myers and Watson the effect of varying the design conditions can be investigated within the range of pressure, temperature, and conversion of the experimental data from which the apparent reactions were derived, provided that sufficient data are available to establish the range of applicability of the apparent reactions.

The chief advantage of the method of Schutt is its relative simplicity; a single design integration can be performed in 2 or 3 man-days. However, a further reduction in the labor required would be desirable.

In the present work the design of a reactor for pyrolysis of ethane by use of the method of Myers and Watson (*6*) is presented. The three objections to the use of this method have been mainly overcome. First, the calculations have been programed and carried out with an I.B.M. card-programed digital computer. By this means the time required for a design integration has been reduced to 4 hr., so that the use of the more rigorous design method is now economically feasible. The same calculations have also been done with an I.B.M. type-650 computer. The time required was 30 min. Second, because of the availability of more experimental data it was possible to select the apparent reactions and reaction-rate expressions for ethane pyrolysis entirely on the basis of experimental evidence. The resulting kinetic system reproduces the experimental data satisfactorily. Third, carrying out a series of design integrations yielded a realistic sample design. In particular, the heat-flux pattern conformed to the capacity of the modern reactor furnace and to the empirical rules which have recently been found for obtaining a high conversion of ethane with minimum formation of coke.

Fig. 3. Variation of apparent over-all rate constants k_2 and k_4 with temperature.



Prevention of Coke Formation

A cross-sectional scheme of a reactor furnace is shown in Figure 1. By proper arrangement of the burners and the coils, a wide variation in the heat-flux pattern can be obtained with local fluxes as high as 14,000 B.t.u./(hr.)(sq.ft.). It will be shown how this flexibility of the modern reactor furnace is utilized to obtain high conversion without excessive carbon formation which would eventually plug the reactor tubes.

Table 2.—Approximate Values of Heat Flux in Critical Reaction Zone

Feed	Tube I.D., in.	Heat flux, B.t.u./(hr.)(sq.ft.)*
Ethane	4.0	7,000-10,000
	3.0	5,000- 7,500
	2.5	4,500- 6,500
Propane	4.0	4,000- 6,500
Naphtha	4.0	3,000- 4,000

* Outside surface.

The reactor consists of a series of alloy-steel tubes called a *coil*. The feed stock enters at one end under pressure and is preheated in a convection section to a temperature at which practically no conversion takes place. In the remainder of the coil heat is applied to raise the temperature rapidly and effect the conversion.

The cause of coke formation is understood qualitatively, but the theory has not been developed sufficiently to allow a theoretical prediction of coil design to prevent coking; however, some empirical rules have been discovered for the design of such coils.

Most of the free radical reactions which produce the secondary products (including coke) are of second order, i.e., the rates of these reactions are approximately proportional to the square of the absolute pressure. The local rates of these reactions are also influenced by temperature and by the extent of primary decomposition which has occurred. The empirical rules must take these variables into account.

The gas velocity across the tube cross section is, of course, not uniform. There is a film, or layer of retarded flow, near the tube walls, and it is here that most of the coke formation occurs. The thickness of the retarded-flow wall layer is a function of the gas velocity. Therefore, high mass velocities are used not only to aid heat transfer and to reduce tube-metal temperatures, but also to minimize coking. This practice does not eliminate the problem, as the secondary reactions which lead to coke formation are favored by the high pressures required to overcome pressure drop at high gas-flow rates. However, the partial pressures of the hydrocarbons can be reduced by steam dilution.

Another way to minimize the formation of coke is to use the highest obtainable heat flux in the middle zone of the coil, from the point where cracking begins to a point where it has progressed to approximately half the extent of conversion of the key

Table 1.—Average Heat Transfer Rate in Coil Section Above 1,000° F.

Tube O.D., in.	Heat Flux B.t.u./(hr.)(sq.ft.)*
2	9,000
3	10,000
3.5	10,500
4.0	12,000
4.5	12,500

* Outside surface.

constituent for which the reactor is being designed. In the remaining zone of higher conversion the heat flux should be just high enough so that the temperature of the reacting gas is gradually rising. By the use of such a heat-flux pattern the temperature of the reacting gas is raised almost to its final value well before the desired conversion is attained. Thus, the average temperature of the reacting gas is relatively high, pyrolysis occurs rapidly, and a shorter coil is required. As a guide, the effective contact time should be less than 1 sec.

There are two reasons why the use of such a heat-flux pattern minimizes coke formation. In the first place, a high heat flux requires a large temperature drop from the outside tube wall to the bulk of the gas. Secondly, the temperature of the retarded-flow layer is high relative to the bulk of the gas, so that the pyrolysis reactions proceed rapidly in the wall layer. This condition is not serious in the middle zone of the coil, but in the end of the coil, where the average conversion is already high, the pyrolysis reactions would proceed to such an extent in the wall layer that excessive coke formation would occur. This situation is avoided by use of the heat-flux pattern described previously. In the second place, raising the average temperature at which pyrolysis occurs favors the primary decomposition of ethane over the secondary reactions and thus leads to coke formation. This result follows from the fact that the activation energy of the primary dissociation is considerably higher than the activation energies of the secondary reactions.

A pyrolysis furnace is usually designed as a combination radiant and convection type of heater where the extent of the convection heating surface is dictated by considerations of fuel economy. The reactant flows countercurrent to the combustion gases and enters the radiant tubes, disposed in the combustion chamber, at a temperature below which essentially no decomposition has taken place. This temperature is in the order of 1,000° F. for ethane and propane pyrolysis operation.

The selection of the heat transfer rate in the radiant section is very much dependent on the size of the tube. The problem is to attain the temperature level compatible with the postulated conversion and the equilibrium consideration, i.e., the permissible equilibrium approach, while avoiding a high heat flux in the zone of high conversion. The larger the tube diameter, the higher the heat intensity must be in view of the higher volume-to-surface ratio of the coil. For the pyrolysis of ethane in a 4-in. diam. tube, the average heat flux in the radiant section should be about 12,000 B.t.u./(hr.)(sq.ft.), and since lower heat transfer rates should prevail in the end zone, the heat flux in the rest of the radiant coil may be about 13,000 B.t.u. or higher, which is within the capacity of a modern furnace. Values for the average heat transfer rate in the radiant coil are given in Table 1 as a guide for the arrangement of the tubes in the combustion chamber.

A lower limit for the heat flux in the end zone of the coil is set by the desirable feature that the temperature in this zone should rise only moderately or to the extent of maintaining a certain equilibrium approach. Thus the heat flux must be somewhat larger than is necessary to supply the heat of reaction. The value of the heat flux in this critical end zone given in Table 2 may be used as a guide.

Equilibrium-Approach Criterion

Experience in designing commercial reactors has led to the conclusion that coke formation is not excessive if the approach to equilibrium of the primary decomposition of ethane is kept below a certain value. This rule is called the *equilibrium-approach criterion*. The theoretical significance of this observation in terms of the mechanism of coke formation has not been worked out, since the mechanism appears to be extremely complex. However, the equilibrium approach criterion has proved its effectiveness in the design of large-scale reactors. The existence of apparent chemical equilibria among ethane, ethylene, and hydrogen in the cracking products of many types of hydrocarbons has been demonstrated by Linden and Peck (*5*).

The primary decomposition of ethane into ethylene and hydrogen is a reversible reaction. (Of course, the equilibrium is continually being displaced by the secondary reactions.)

The equilibrium constant is given by

$$K_1 = \frac{P_{C_2H_4} \times P_{H_2}}{P_{C_2H_6}} = 3.31 \times 10^{-4.0147/T} \qquad (1)$$

According to the equilibrium-approach criterion, at all points in the reactor the value of the expression on the right of Equation (*1*) must be less than a certain fraction of the value of K_1. Since K_1 is an increasing function of temperature, the allowable extent of conversion may be increased by raising the temperature, but this must be done without utilizing too high a heat flux. In the middle reactor zone the heat flux is limited by furnace capacity, and in the end zone it is best kept only slightly larger than the heat of reaction to avoid excessive tube-wall temperature. The higher conversions can also be obtained by using higher steam dilutions and thus reducing the partial pressures.

The allowable approach to equilibrium depends on the mass velocity of the reactant in the tube as well as on the amounts of other constituents, especially propylene, present in the feed stock. For a reasonable mass velocity in the order of 25 lb./(sq.ft.)(sec.) the approach to equilibrium may be as high as 65%. For a mass

Fig. 4. Variation of apparent over-all rate constants k_5, k_6 and k_7 with temperature.

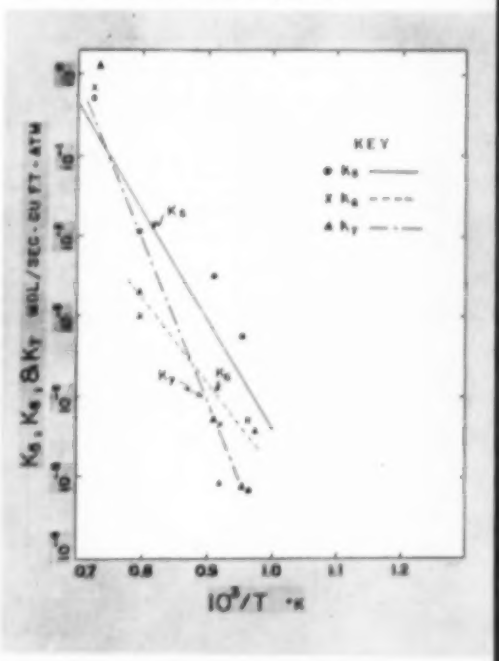


Table 3.—Ethane Pyrolysis Data

Source	Temperature, ° F.	Pressure, atm.
(14)	1,090	1.42
(3)	1,500	1
(1)	1,795	1.17
(15)	2,010	0.066
(7)	1,330–1,600	1

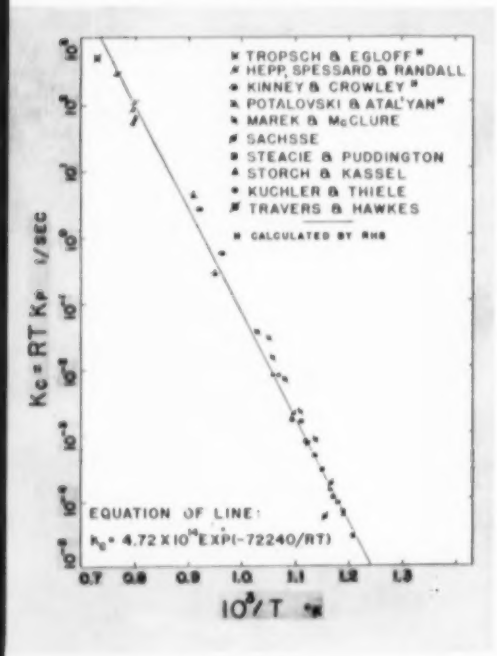
Table 4.—Conditions for Sample Calculation

Feed, mole %	
C_2H_6	2.1
C_2H_4	94.4
C_3H_8	2.4
C_4H_{10}	1.1
Steam, % (based on moles of hydrocarbon feed)	20
Mass flow rate, lb./(sq.ft.)(sec.)	25
Limiting equilibrium approach, %	65
Required conversion, %	65
Outlet pressure, lb./sq.in. gauge	10
Tube dimensions	
Inside diameter, in.	4
Length, ft., each	24
Return bends, in. (on centers)	9

velocity of about 10 to 15 lb./(sq.ft.)(sec.) it should be less than 50%. If propylene is present in excess of 5 mole %, the approach to equilibrium should be less than 50% even if a relatively high mass velocity is used.

These empirically established criteria apply to reaction coils where the heat-intensity distribution, longitudinally as well as circumferentially, is relatively uniform.

Fig. 2. Variation with temperature of rate constant for primary decomposition of ethane.



Method of Calculation

The method of calculation employed is that used by Myers and Watson (*6*), and the system selected for study is the pyrolysis of ethane. The actual mechanism of ethane conversion by way of free radicals is not firmly established; consequently, apparent over-all reactions have been used which would reproduce the experimental conversion data. The resulting kinetic expressions may be applied over the range of temperature and pressure of the data on which they are based. (See Table 3). The data consist of product distributions and contact times for various degrees of conversion of ethane. As the experiments were done in small-scale equipment, the surface-to-volume ratio was large; therefore, the experiments took place at practically constant temperature and pressure.

The problem was to find apparent over-all chemical reactions and expressions for the rates of these reactions which, when used in a stepwise integration, would reproduce the data. The reactions and rate expressions* given in this section were determined by a trial process, the units recommended by Hougen and Watson (*2*) being used.

$$C_2H_6 \rightleftharpoons C_2H_4 + H_2$$

$$r_1 = \frac{k_1 P}{n_t}\left[n_{C_2H_6} - \frac{n_{C_2H_4} n_{H_2} P}{K_1 n_t}\right] \quad (2)$$

$$C_2H_4 + 2H_2 \rightleftharpoons 2CH_4$$

$$r_2 = \frac{k_2 P}{n_t}\left[\frac{P}{n_t} n_{C_2H_4} \sqrt{n_{C_2H_6} n_{H_2}} - \frac{n_{CH_4}}{K_2}\right] \quad (3)$$

$$C_2H_4 \rightarrow 0.25C_4H_6 + 0.125C_4H_8 + 0.125C_4H_{10} + 0.125H_2$$

$$r_3 = 0.012 r_1 P \quad (4)$$

$$C_2H_4 \rightarrow 0.333C_6H_6 + H_2$$

$$r_4 = \frac{k_4 P^2}{n_t^2} n^2_{C_2H_4} \quad (5)$$

$$C_2H_4 \rightarrow C_2H_2 + H_2$$

$$r_5 = \frac{k_5 P}{n_t^2} n^2_{C_2H_4} \quad (6)$$

(first order with respect to pressure)

$$C_2H_4 \rightarrow 2C + 2H_2$$

$$r_6 = \frac{k_6 P^2}{n_t^2} n^2_{C_2H_4} \quad (7)$$

$$C_2H_4 + C_2H_6 \rightarrow 0.952C_3H_6 + 0.381C_3H_8 + 0.62H_2$$

$$r_7 = \frac{k_7 P}{n_t}\left[n_{C_2H_6} - \frac{n_{C_2H_4} n_{H_2} P}{k_1 n_t}\right] \quad (8)$$

Each of these seven reactions gives at least one unique product. Hence, the rate of each reaction could be calculated for small increments of conversion from the expression.

$$r = \frac{\Delta n}{V \Delta t} \quad (9)$$

The rates were calculated from Equation (*9*) for each increment of conversion by use of the experimental data. Rate expressions, Equations (*2*) to (*8*), were then solved, a number of values of k being obtained for each reaction. A satisfactory rate expression must give the same value of k for all degrees of conversion. Expressions (*2*) to (*8*) were chosen in such a way as to satisfy this criterion. Actually, the calculated values of k vary by as much as a factor of two in some cases. In order to find the best average values of the k_i, a stepwise reactor integration was programed for the computer. The program for this calculation comprised simply a substitution of the preliminary rate expressions into Equation (*9*). The calculation was repeated for successive time intervals until a product distribution was obtained.

The computed product distribution was compared with the experimentally determined one, and the values of the rate constants used were adjusted proportionately to any discrepancies in the product distribution. With new

* These rate expressions are not intended to imply any particular reaction mechanism. They were selected solely for the purpose of reproducing the product distributions for the pyrolysis of practically pure ethane over the range of temperatures, pressures, and conversions of the available data. The expressions given for r_5 and r_6 would be inconsistent if they represented a reaction mechanism, as these expressions imply an order of reaction with respect to pressure which is different from the order of reaction with respect to number of moles. However, expressions which might seem more logical were tried, and they do not reproduce the experimental data so well as the expressions used. This observation confirms the known fact that the true reaction mechanism is more complicated than might be inferred from the given rate expressions, but this fact is of no significance for the purpose of this paper. Expression r_5 may also appear illogical as it implies that ethylene decomposition is proportional to ethane decomposition rather than to the amount of ethylene present. It could be thought that at very low conversions the calculated amount of ethylene decomposed might exceed the amount of ethylene formed, but calculations have shown that such is not the case. At the higher conversions of the data listed above, this expression reproduces the data more accurately than expressions which involve the amount of ethylene present.

rate constants, a new product distribution was calculated. This procedure was repeated until the calculated product distribution agreed with the experimental one. In the same way, average rate constants were calculated from each set of experimental data.

By means of this comparison method of adjusting rate constants, it was possible to use literature data in which the product distributions were not completely reported; thus, the inclusion of data from a broader range of operating conditions was facilitated by use of the computer.

Reaction-Rate Constants

The rate constants k_i evaluated from pyrolysis data are shown in Figures 2, 3, and 4.

The expression given for the rate constant k_1 is equivalent to an over-all rate constant which has previously been found most satisfactory for use with the simplified method of design of commercial reactors. This expression has been plotted in Figure 2 in concentration units for comparison with rate constants determined by a number of investigators. These other experimental points were taken from the work of Steacie (*10*) and are based on experimental reaction rates extrapolated to zero conversion. The newly calculated points are based on calculations made with the system of apparent over-all reactions, Equations (*2*) to (*8*). The agreement among the experimental points and the rate-constant expression is good.

The inconsistencies among experimental points in Figures 2, 3, and 4 are of a magnitude which could readily result from errors in measuring the temperature of the reacting gas and the contact time, as well as differences in experimental reactor design which affect the tube-wall-layer thickness and temperature.

Program for Design Calculation

The constant-temperature computer program used for deriving kinetic expressions was expanded to permit design of a reactor with varying temperature and pressure. It was necessary to derive formulas for properties, such as gas heat capacity and viscosity, heat of reaction, and pressure drop.

Heat capacities of the pure hydrocarbons were derived from the data of Stull and Mayfield (*13*) and expressed in the form of polynomials in temperature. Expressions for the other quantities were derived in the manner discussed by Schutt (*9*) and Myers and Watson (*6*).

The technique of the stepwise trial-and-error reactor-design integration used here has also been discussed by these authors (*9, 6*).

The steps in the design program are given below:

A. Store basic data:
Feed composition = n_{i_0}, moles of *i*th component/mole of feed
Feed temperature = T_0, ° K.
Feed pressure = P_0 atm.
Tube volume increment/feed rate = V/F, cu.ft./(sec.)(mole)

B. Assume temperature rise ΔT, pressure drop ΔP, and extent of reaction Δn_i all per coil-length increment (1 tube).

C. Compute averages over 1 tube of T, P, $\bar{n}_i$, and expansion $\bar{n}_t$, moles of products/mole feed.

D. Compute gas properties and conditions at the end of the tube:
Heat capacity = C_p = Centigrade Heat Units/(° K.)(mole of feed)

$$\bar{C}_p = \Sigma n_i A_i + (\Sigma n_i B_i)\bar{T} + (\Sigma n_i C_i)\bar{T}^2$$

Viscosity = μ, micropoises, from reduced correlation of Hougen and Watson (*2*)
$\ln \mu_r^{0.2} = -0.1208 + 0.1354 \ln T_r$
Pressure drop = ΔP, atm.
$\Delta P = 7.41 \times 10^{-6} \mu^{0.2} n_t \bar{T}/P$ for 4-in. I.D. tube with mass flow rate 25 lb./(sq.ft.)(sec.)
Rate constants = k_i from kinetic correlation
Equilibrium constants = K_i
Rates of reaction = r_i, from rate expressions
Extent of reactions = $r_i \Delta V/F$
Extent of conversions = Δn_i, from stoichiometry
Heat due to increment of reaction at 800° K. = ΔH_{800} C.H.U./mole of feed converted

$$\Delta H_{800} = \Sigma \Delta H_{i_{800}} r_i \Delta V/F$$

where
$\Delta H_{i_{800}}$ is obtained from basic thermodynamic data

Heat due to increment of reaction at local temperature = ΔH_T, C.H.U./mole of feed converted

$$\Delta H_T = \Delta H_{800} + \int_{800}^{T} \Delta C_p dT$$

where
$\Delta C_p = \Sigma \alpha_i \Delta n_i + (\Sigma \beta_i \Delta n_i)\bar{T} + (\Sigma \gamma_i \Delta n_i)\bar{T}^2$
Temperature rise = $\Delta T'$ ° K.

$$\Delta T' = (Q - \Delta H)/C_p$$

where
Q = heat flux, C.H.U./(tube)(mole of feed)

E. Repeat steps C and D with new values of $\bar{T}$ and n_t.

F. If T' from the second calculation differs from T' from the first calculation by more than 1° K., repeat steps C and D.

G. Compute equilibrium approach:

$$\text{Approach} = \frac{n_{i_0}\mu_i n_{t_0} P}{n_{i_0}\mu_0 n_t K_i}$$

If this quantity exceeds 0.65, the heat flux should be adjusted.

H. When T' and all other results become constant, compute and print new values of n_i, T, and P. Store these and use them as starting values for the next tube.

I. Toward the end of the coil the heat flux should be patterned in the manner previously described, in conformity with the design of the furnace, the configuration of the interior walls, the arrangement of the burners, and the reaction coil elements.

J. The outlet temperature, pressure, and degree of conversion should approximate the specified values. If they do not, the whole

Fig. 5. Operating conditions calculated along length of reactor coil.

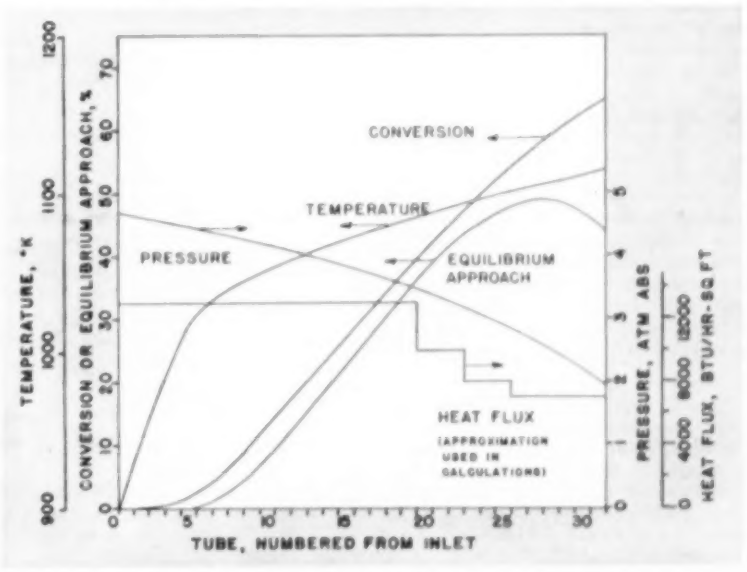


Table 5.—Comparison of Calculated Product Distribution with Product from Commercial Operation

Component	Coil outlet stream, mole % (HC only) Calculated	Actual operation *
H_2	34.6	33.9
CH_4	7.2	7.5
C_2H_2	0.3	0.3
C_2H_4	31.7	32.5
C_2H_6	21.4	21.8
C_3H_6	2.3	1.3
C_4H_8	0.9	0.6
C_4	0.8	1.0
C_5 (inc. carbon)	0.8	1.1

* Results with a reactor operating under the following conditions:

Tube size, in. I.D.	3.94
Mass velocity, lb./(sq.ft.)(sec.)	23.5
Coil outlet pressure, lb./sq.in. gauge	10.2
Coil outlet temperature, ° F.	1,505
Steam, moles/100 moles of feed	20

process should be repeated with new inlet conditions or a new heat flux pattern.

Sample Calculation

The sample calculation illustrates the conditions obtained along the length of a pyrolysis coil, as well as the methods of design which have been discussed. The design was made to conform to the conditions given in Table 4.

The feed composition is one which might be obtained by recycling the product from a purification plant. The reasons for the choice of pressure and tube size have been discussed by Schutt (*9*), and the results of the calculations are summarized in Table 5* and Figure 5.

A first coil integration calculation based on the reaction rates of Figures *2*, *3*, and *4* showed that the composition of the coil-effluent stream agreed in major respects with the composition of the effluent from an operating reactor. The amounts of some of the secondary products differed slightly, however. It is believed that data from a full-scale reactor are more reliable than data from small-scale experimental reactors because the temperature pattern throughout the coil is known more precisely and because larger amounts of product are available for analysis. In order that the rate constants reported here may be used with confidence for design purposes, these rate constants have been adjusted by a trial procedure so that the calculated coil-effluent composition agrees in detail with the composition of an operating reactor, as shown in Table 5. The reaction rate constants k_i and equilibrium constants K_i determined in this way are listed below as functions of temperature T, °K:

$$k_1 = (3.46 \times 10^{16}/T)e^{-69,300/T}$$
$$K_1 = 3.31 \times 10^{-7}e^{+9,050/T}$$
$$k_2 = 7.50 \times 10^{7}e^{-39,300/T}$$
$$K_2 = 1.0$$
$$k_3 = 4.09 \times 10^{6}e^{-33,400/T}$$
$$k_5 = 9.13 \times 10^{7}e^{-39,500/T}$$
$$k_6 = 4.51 \times 10^{6}e^{-34,500/T}$$
$$k_7 = 1.04 \times 10^{14}e^{-64,200/T}$$

The frequency factors of some of these rate constants differ from the values shown in Figures *2*, *3*, and *4* by a factor of *2* in some cases. This difference is believed to be within the accuracy of the experimental pyrolysis data and represents reasonable accuracy for pyrolysis reaction data measurements at these temperatures. The activation energies have not been changed from the values represented by Figures *2*, *3*, and *4*.

In Figure 5 are shown the calculated conversion, temperature, pressure, and equilibrium approach along the coil length. The heat-flux values used in the calculations are also shown in Figure 5; the actual heat flux would of course be a smooth function. It may be seen that the heat-flux and temperature patterns conform to the requirements mentioned in the preceding discussion. It will also be seen from Figure 5 that there is no close approach to equilibrium; hence, the coil may be operated safely at the conversion specified, and long runs are assured.

Conclusion

An understanding of the conditions which affect coke formation in pyrolysis reactors has resulted in modern techniques permitting the design of reliable reactors which produce an optimum yield of desired olefins.

A suitable goal for reactor technology is the development of the theory to an extent which would permit the calculation from experimentally determined rate functions of all necessary information for the design of reactors operating over a wide range of conditions. In the present work it has been possible to obtain expressions for the rates of production of secondary products in ethane pyrolysis with sufficient accuracy for calculation of the heat effect and gas expansion. By combination of this method with empirical criteria for prevention of coke formation, a realistic reactor design has been demonstrated. The use of digital computers was essential for this work.

A further improvement would allow the calculation of local rates of carbon formation, freeing the designer to investigate radical designs for which empirical coke-formation rules are not available. Such improvements would require a more rigorous, detailed formulation of the kinetics of ethane pyrolysis, such as might eventually be deduced from a thorough understanding of the free radical mechanisms involved.

Notation

- k_i = reaction velocity constant, moles/(sec.)(cu.ft.)(atm.) for a first-order reaction, moles/(sec.)(cu.ft.)(atm.^{2}) for a second-order reaction
- K_1 = equilibrium constant for dehydrogenation of ethane, atm.
- n_i = moles of ith component/mole of feed
- n_t = expansion, total moles/mole of feed
- Δn = change in number of moles of the unique product
- P = total pressure, atm.
- $P_{C_2H_4}$, P_{H_2}, $P_{C_2H_6}$ = partial pressure of ethylene, hydrogen, and ethane, respectively
- r_i = rate of ith reaction, moles converted/(sec.)(cu.ft.)
- T = temperature, °K.
- Δt = increment of contact time, sec.
- V = volume of mole of feed at the reaction temperature and pressure, cu.ft.

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* Tables of product distributions and other quantities calculated along the length of the reactor coil have been deposited as Document 5123 with the American Documentation Institute, Photoduplication Service, Library of Congress, Washington 25, D. C., and may be obtained for $1.25 for photoprints or 35-mm. microfilm.

THE FALLING-FILM HYDROCHLORIC ACID ABSORBER

In the accompanying pages the progress in improving impervious graphite falling-film absorbers for production of hydrochloric acid is traced. Advancements made in the design and in the development of correlations for predicting performance, based in part on earlier work (*1, 2*), are also noted.

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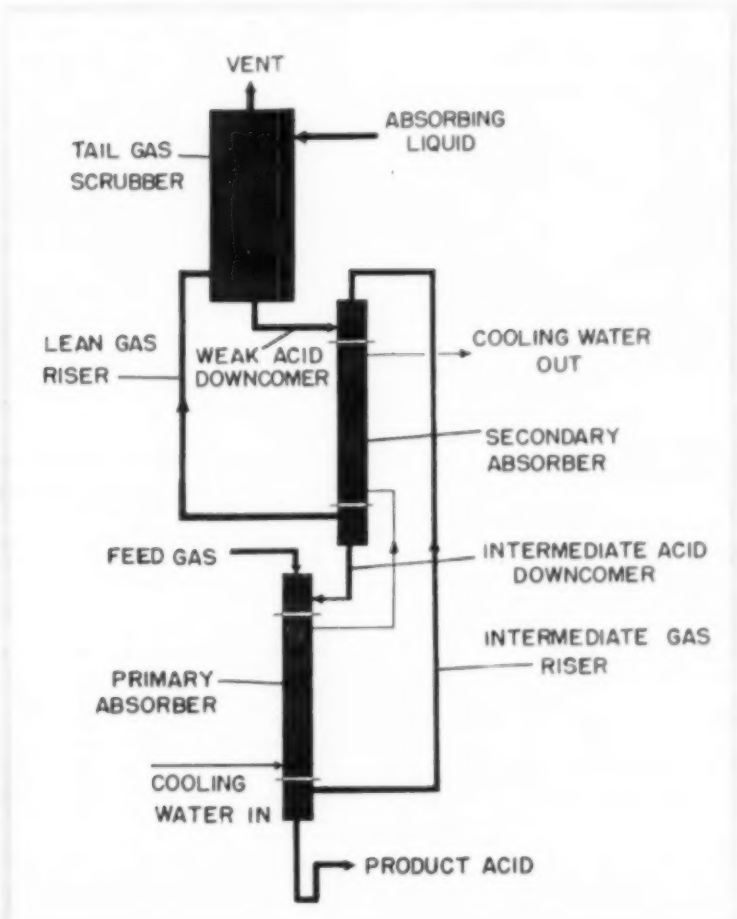
An initial report on impervious graphite falling-film absorbers for production of hydrochloric acid was made late in 1945 (*5*). At that time, the equipment for these absorbers was relatively new, and much that was known about it was empirical. Since that time commercial use has proved the advantages of the basic design and naturally has pointed up the need for certain improvements.

Equipment

The basic equipment illustrated in Figure 7 is used principally for the production of hydrochloric acid from gases with wide variations in hydrogen chloride content, ranging from 40 to 100 mole %.

Fig. 1. Typical flowsheet, falling-film hydrochloric acid absorbers.



The system consists essentially of a vertical shell-and-tube exchanger known as the cooler-absorber, a packed tail gas scrubber, and interconnecting piping.

The gas to be absorbed enters the system through an inlet at the upper end of the heat exchanger and flows down inside the tubes parallel with the flow of absorbing liquid. Nonabsorbable gases, together with unabsorbed hydrogen chloride reaching the bottom of the tube bundle, pass through a riser to the bottom of the tail gas scrubber. The gas flows up through the packed scrubber, countercurrent to the liquid flow, and the inert gases leave through a vent in the top. The absorbing liquid is fed through an inlet at the top of the tail gas scrubber and falls over the packing countercurrent to the rising gas. The acid leaving the tower is fed to the top tube sheet of the heat exchanger. The liquid then passes over the tangential V-notch weirs provided for each tube and flows down as a film around the inner periphery of the tubes. The acid produced leaves the bottom of the tube bundle through a seal assembly. In this way, the heat exchanger functions as a number of water-cooled, wetted-wall columns in parallel.

Downward cocurrent flow of gas and absorbing liquid in the heat exchanger is used because higher capacities can be attained than with upward gas flow. Practical gas flow rates with cocurrent operation are many times greater than the flooding velocity for countercurrent flow. The cocurrent gas flow does require, in most cases, a tail gas scrubber which might be eliminated with countercurrent flow. However, countercurrent operation of the heat exchanger imposes such severe restrictions on the operating range that cocurrent flow always has been the economic choice and the choice of operators who must have equipment designed to handle large variations of gas flow rates.

Downward gas flow is also of value when the gas to be absorbed is hot. By a combination of sensible heat transfer

* A division of Union Carbide & Carbon Corporation.

and hydration, hot feed gases are brought reasonably close to the inlet cooling water temperature in the tubes commonly used for constructing the heat exchanger. Gases of 700° F. have been fed to an installation for many years with little effect on the product acid concentration. Separate cooling equipment is usually provided for any countercurrent absorber handling gas at 700° F.

For small absorbers with capacities up to 500 lb./hr. it is possible to mount the tail gas scrubber directly over the heat exchanger, enabling the complete system to be further streamlined by enclosing within the exchanger the gas line connecting the bottom of the exchanger with the bottom of the scrubbed. Such a modern Karbate* impervious graphite absorber is shown in Figure 2.

The simplest equipment for the production of commercial strength acid up to 36% HCl is a water-cooled impervious graphite tower (*7*). The falling-film absorber is provided with a tail gas scrubber ranging in size from one-third to one-tenth the tower volume required to produce commercial strength acid. Usually, the differential in tower costs will more than cover the cost of the impervious graphite heat exchanger and piping required for the falling-film-type absorber. In addition to the saving in first cost, the product acid from a falling-film unit is generally cooler, and when water is the absorbing liquid, the falling-film absorber can also be designed for no vent losses.

The falling-film system with its heat exchanger and tail gas scrubber permits localizing corrosive conditions when chlorine is present in the gases to be absorbed. Chlorine reacts with water to form hypochlorous acid, which will slowly oxidize impervious graphite. However, the presence of sufficient hydrochloric acid inhibits the formation of hypochlorous acid. Since no heat is transferred in the tail gas scrubber of a falling-film absorber, the scrubber can be constructed of materials resistant to chlorine in the presence of water; or, hydrochloric acid can be fed to the top of the tail gas scrubber when it is made of impervious graphite.

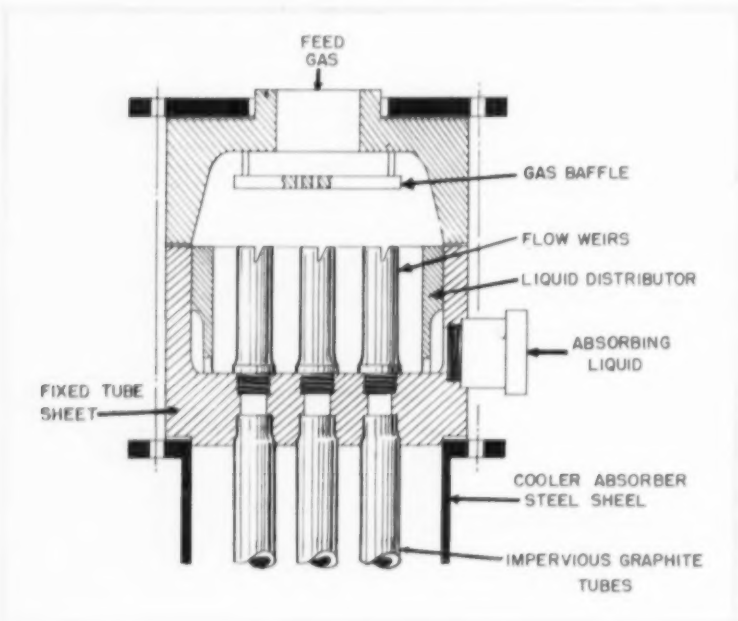


Fig. 3. Fixed end construction, "Karbate" impervious graphite falling-film absorbers.

* Karbate is a registered trade-mark of Union Carbide and Carbon Corporation.

Liquid Distribution

In order to make most effective use of all the mass transfer surface provided in the heat exchanger, the entire surface should be wet with acid. Tests have established that the minimum flow of water to wet all the surface of a wetted-wall column is about 50 lb./(hr.)(ft.) periphery for a single tube. When allowance is made for the normal distribution pattern in a multiple-tube exchanger, the minimum recommended water flow is about 100 lb./(hr.)(ft.) (*5*).

Experimental work on wetted-wall columns has, invariably, been carried out with single vertical tubes (*1, 2, 4*), that is, a single tube provides ideal liquid and gas distribution compared with the distribution obtained in commercial falling-film absorbers, which have been constructed containing as many as 349 ¾-in. I.D. tubes. In recognition of this, the velocity of the acid in the line entering the top tube sheet of the heat exchanger was kept below 1 ft./sec. The weirs attached to the top of each tube were threaded to provide vertical adjustment.

In recent years it became apparent on larger absorbers that these precautions in design were not sufficient. Acid entering the tube sheet welled up over the rows of weirs immediately adjacent to the acid inlet; this action caused those tubes to take a disproportionate share of the acid feed.

At the same time it was recognized that adjustable weirs were not only tedious to adjust but also provided improved distribution for only one particular liquid flow rate to the heat exchanger.

Recently the armoring of connections to Karbate impervious graphite heat exchangers has placed the preferred location of the gas inlet to the exchanger at the top of the exchanger on its axis. Unless the gas flow entering from this position is baffled, it will cause a local depression of the liquid level on the tube sheet immediately under the gas inlet.

The arrangement shown on Figure 3 has been developed to provide a liquid distributor ring encompassing the flow weirs. The liquid enters the pool on the tube sheet at low velocity from a number of evenly spaced openings around the circumference of the ring. Uniform, close-tolerance flow weirs with a positioning shoulder above the threads have been developed. The shoulder eliminates adjustments in the field.

To keep the openings between the flow weirs large enough to minimize resistance to liquid flow and thereby minimize hydraulic gradient across the tube sheet, the weirs are made 5 in.

Table 1.—Effect of Distribution on Falling-Film Absorber Operation

Heat exchanger—139 tubes, ⅞-in. I.D. × 108 in. long. Tail gas scrubber—30-in. I.D.; feed gas—100% HCl

	A	B
Liquid distribution ring, gas baffle and shouldered weirs	No	Yes
Liquid distribution, standard deviation—% of mean flow	48	15
Feed gas flow rate, lb./hr.	7100	7000
Feed water temperature—° F.	80	79
Cooling water—flow, gal./min.	415	312
—inlet temperature, ° F.	80	79
—outlet	98	103
Product acid—wt. % HCl	32.2	34.0
—temp. ° F.	132	111
Acid produced in tail gas scrubber—wt. % HCl	14.5	12.1
Tail gas scrubber—vent temp. ° F.	..	78
—HCl loss	Yes	No

or higher. They have four tangential ½-in. deep V-notches, imparting a swirling motion to the liquid as it enters the tube. Because four rather than one V-notch is provided, a moderate amount of solids capable of plugging the notches can be tolerated in the acid. However, periodic cleaning is recommended in this situation. A single ⅞-in. I.D. weir can handle water flows up to 500 lb./hr. before running full.

The liquid distribution ring, shouldered weir, and gas baffle (Figure 3) are the subject of a patent pending.

The degree to which performance is affected by attention to acid distribution was shown by tests on a large installation. Results obtained are summarized in Table I. The unit in Table I was judged to have a maximum capacity of 6,000 lb./hr. with vent free of HCl when producing 32% acid without the liquid distribution ring, gas baffle, and shouldered weirs. It was found to have a capacity of 9,000 lb./hr. with the improved liquid distribution producing 32% acid without vent losses.

The standard deviation of 15% of mean flow shown in Table I attainable with the improved fixed tube-sheet construction compares with the 48% standard deviation typical of the older construction. In an older unit handling 0.0040 gal./(min.)(tube) in 128 tubes ⅞-in. I.D., the standard deviation was found to be 88%. The best distribution attainable with the original tube-sheet construction was on a unit with 235 tubes handling 0.095 gal./(min.)(tube) in which the standard deviation after careful adjustment of the weirs was 27%. This required raising the flow weirs immediately adjacent to the liquid inlet approximately ⅛ in. to compensate for the welling over of the acid which entered at only 0.6 ft./sec. in the acid line attached to the tube sheet.

Performance

In time, the performance of falling-film-type absorbers will be predicted by performing the point-to-point calculations down the tubes as outlined by Coull, *et al.* (*1*), probably assisted by a computer. At the present time some of the basic relationships required for the point-to-point calculations are not known with sufficient degree of precision to justify the calculations. The absorption of hydrogen chloride in water involves diffusion of hydrogen chloride into the acid at the top of the tube counter to evaporation of water, followed by diffusion of both hydrogen chloride and water vapor into the acid at the bottom of the tube. In almost all practical situations, an inert gas is present. Such situations call for relationships capable of predicting simultaneous diffusion of two gases in the presence of a third. Little work has been done in this direction. Point-to-point calculations are also hampered by the lack of reliable data on heat transfer to falling-films with surfaces disturbed by high velocity gases.

The most satisfactory procedure at this time for predicting performance is based on the terminal conditions at the top and bottom of the wetted-wall columns with the use of over-all driving forces. This takes the form of Equation (1)

$$N_{A_a} - N_{A_t} = K_g P_{am} A \quad \ldots \quad (1)$$

Arithmetic-Mean Partial Pressure Driving Force

Better correlation of mass transfer coefficients has been found by employing the arithmetic-mean driving force. Dobratz, *et al.* (*2*) evaluated the over-all mass transfer coefficients in terms of the logarithmic mean driving force in their work with wetted-wall hydrochloric acid absorbers. It was calculated from the log mean average of the difference between the partial pressure of the HCl in the gas and the equilibrium vapor pressure of HCl over the liquid at the inlet and outlet of the absorption tube. Perhaps the better correlation with the arithmetic mean is due to the marked deviation of the HCl-water system from Raoult's Law.

Because of the uncertain amount of water vapor in the gases leaving the absorption tubes, all investigators to date, including the present authors, have usually neglected the water vapor content of the gas in calculating partial pressure driving force. However, in the case of many dilute gases, particularly those arising from the decomposition of metallic chlorides in gas-fired rotary kilns, the gases come into the absorption system containing more water vapor than HCl on a volumetric basis. In such cases, it has been customary to take into account the water vapor at the top of the tube, but to neglect it at the bottom of the tube, in calculating the arithmetic mean pressure of HCl. This is not wholly inconsistent in view of the lack of information.

Mass Transfer Coefficients

The instantaneous local rate of mass transfer in a wetted-wall column for a two-component system is given by Gilliland's correlation (*4*).

$$\frac{\frac{K_g R T D}{D_V}\frac{P_{B_m}}{P}}{} = 0.023 \left(\frac{DG}{\mu}\right)^{0.83} \left(\frac{\mu}{\rho D_V}\right)^{0.44} \quad \ldots \quad (2)$$

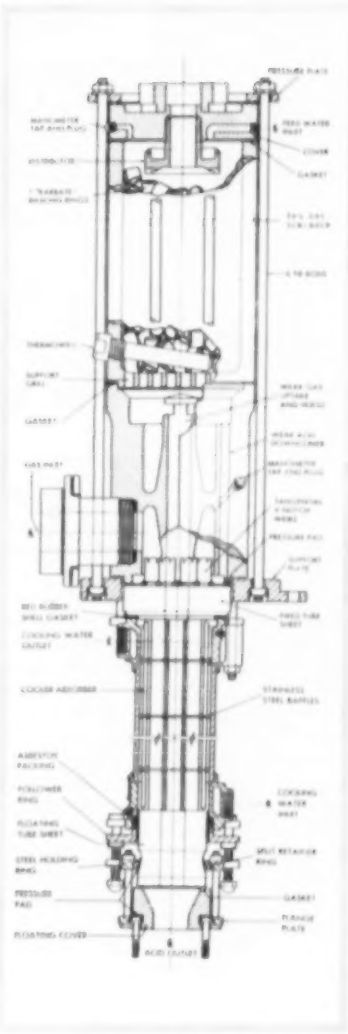
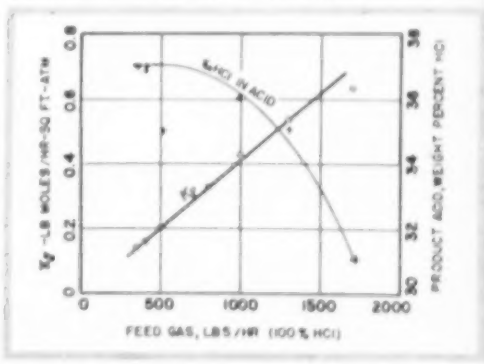


Fig. 2. Detail of "Karbate" impervious graphite Model 8A absorber.

Fig. 4. Typical falling-film absorber performance. Thirty-one ⅝-in. I.D. × 108-in. long tubes. 16-in. I.D. tail gas scrubber. Cooling and feed water at 45° F., (Tail gas scrubber acid temperature controlled at 59-90° F.)



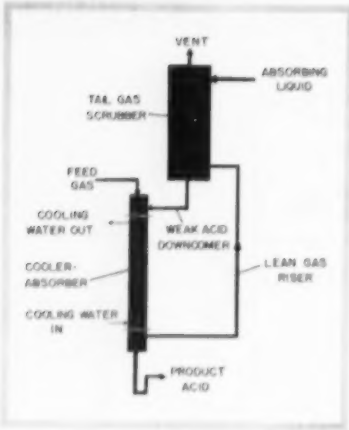


Fig. 7. Falling-film system to provide close approach to equilibrium between feed gas and product acid.

On an over-all basis, work by Dobratz, *et al.* (*2*) suggested K_g was proportional to G_a raised to the 1.8 power, as compared to 0.83 in Equation (*2*). Figure 4 shows the variation of K_g with gas flow rate in a commercial absorber containing thirty-one tubes, ¾-in. I.D.×108 in. long, absorbing essentially 100% HCl emitted by a chlorinator which was operated over a wide range of flow. In line with Figure 4, the prediction of the mass transfer coefficients in absorbers containing a number of tubes is taken as being directly proportional to the inlet mass velocity.

For the same Reynolds number, Equation (*2*) predicts that inert gases heavier than air will decrease the rate of mass transfer. Data on industrial installations substantiate this, but to a somewhat greater degree than predicted by Equation (*2*). On an over-all basis, the not-too-plentiful data show K_g to be inversely proportional to $M_m^{1.75}$ over the range of M_m = 31.4 to M_m = 86.4, where M_m is the average molecular weight of the gas entering the heat exchanger. Until the effect of simultaneous diffusion of HCl and H_2O is better understood, it is simpler to take K_g proportional to $1/M_m^{1.75}$ instead of to

$$D_V \left(\frac{\mu}{\rho D_V} \right)^{0.44}$$

In line with work by Lynch and Wilke (*6*), with water evaporating into helium, air, and dichlorodifluoromethane in a packed tower, qualitative studies of tail gas scrubbers in falling-film hydrochloric acid absorbers show a decrease of *H.T.U.* as the molecular weight of the inert gases increases, for the same mass velocity.

As brought out by Coull, *et al.* (*1*), water vapor plays an important role in the absorption of HCl in aqueous solutions. In the upper portion of the absorption tube, water is vaporized into the gas stream. In the lower portion of the tube, the water vapor is partially condensed. Overall, water vapor appears to retard HCl mass transfer through dilution of the gas stream and by the release of latent heat in the lower portion of the absorption tube; thus the temperature and vapor pressure of HCl in the acid leaving the tube is increased.

The recommended relationship for predicting the mass transfer coefficient on an over-all basis is based on previously reported data (*1, 2*) augmented with data from numerous industrial installations. These data are plotted in Figure 5 * against the inlet Reynolds number divided by the mean molecular weight at the inlet of the tube raised to the 1.75 power. Only data of industrial interest have been used in developing the recommended correlation. The weight flow of water to the top of the absorption tube is equal to or greater than the HCl contained in the entering gas in all industrial installations. This resulted in the exclusion of certain data of Dobratz, *et al.* (*2*).

In accordance with the line under most of the data in Figure 5, for purposes of designing industrial absorption equipment, the recommended relationship is given by Equation (*3*)

$$K_g = \frac{0.0122}{M_m^{1.75}} \left(\frac{DG_a}{\mu} \right) \quad . \quad . \quad . \quad (3)$$

Equation (*3*) is substantially below Equation (*2*), Gilliland's Correlation. It is believed that the interference of water entering the gas at the top of the tube and leaving the gas at the bottom of the tube is the principal cause.

Determination of Equipment Size

The procedure developed for determining the optimum size of heat exchanger for falling-film absorbers is quite similar to that employed in the design of conventional shell-and-tube heat exchangers. After a preliminary selection of the number, diameter, and length of tubes in the heat exchanger has been made, the predicted performance and pressure drop are compared with the duty required by the application. The driving force is determined by a trial-and-error procedure that requires knowledge of the temperature of the acid leaving the heat exchanger. The duty specified for the absorber will include the concentration of HCl in the product acid. The temperature of the product acid will give the equilibrium vapor pressure at the bottom of the tube.

The preliminary selection of the number, diameter and length of tubes in accordance with allowable pressure drop of the gas, and the minimum permissible liquid flow rates (discussed under Liquid Distribution) will enable the calculation of the number of moles of HCl absorbed in accordance with Equation (*1*) after the arithmetic-mean partial-pressure driving force has been determined.

For design purposes, the product acid temperature can be estimated from Figure 6. In determining the temperature rise of the product acid over the inlet cooling water temperature significant amounts of water vapor in the gas fed to the absorption system can be taken into account by adding the water vapor content of the feed gas to the HCl absorbed. In general, cooling water rates and shell-side baffle spacing should be determined to yield shell-side coefficients of about 600 B.t.u./(hr.) (sq. ft.) (° F.). Higher rates of shell-side heat transfer do not appear to have significant effect on the product acid temperature.

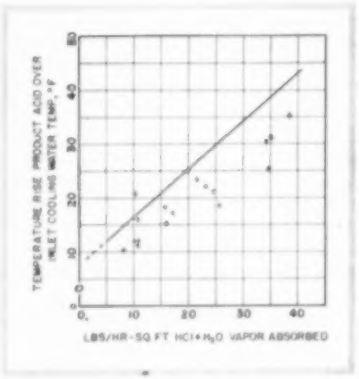


Fig. 6. Temperature rise of product acid over inlet cooling water temperature.

When water is used as feed to the tail gas scrubber, the equilibrium vapor pressure of the HCl in the acid entering the heat exchanger is of little importance in the computation of the arithmetic mean driving force since, in most cases, it will not exceed 5 mm. Hg. If acid is used as feed, its equilibrium vapor pressure at the entrance must be determined more accurately, by trial and error.

A requirement for determination of the arithmetic-mean driving force is the composition of the gas at the top of the absorption tube obtained from the duty specification. The composition of the gas at the bottom of the tube requires an additional equation derived from the material balance.

* Tabular data available from the authors.

$$N_{A_o} - N_{A_t} = N_{A_o} - \frac{N_B P_{A_t}}{P - P_{A_t}} \quad . \quad . \quad . \quad (4)$$

Equations (1) and (4) can be equated by trial-and-error substitution of the partial pressure of the unabsorbed HCl in the gas leaving the exchanger. The value that equates (1) and (4) lies between the partial pressure of the HCl in the feed gas and equilibrium vapor pressure of the HCl in the product acid. When the HCl composition in the feed gas is 100%, trial-and-error calculations are eliminated since only Equation (1) is required.

When the value of partial pressure of the unabsorbed HCl in the gas leaving the exchanger has been determined, it should be inspected to see that it is reasonable. When absorbing HCl in water, it is desirable to limit the portion absorbed in the tail gas scrubber to one-third that in the feed gas to prevent the scrubber from venting water vapor and possibly HCl. Twenty per cent hydrochloric acid feed to the tail gas scrubber limits the desirable level of HCl removal in the tail gas scrubber to one-fourth that in the feed gas. If the unabsorbed HCl at the bottom of the heat exchanger exceeds one-third or one-fourth that in the feed gas, the preliminary selection of the heat exchanger size resulted in a unit too small. On the other hand, a small amount of unabsorbed HCl means that either the exchanger is oversized or that the design conditions impose other limitations than tail gas-scrubber capacity, such as pressure drop.

In the preliminary selection of the number, diameter, and length of tubes, the direct proportionality of K_a to G_a is of considerable significance. For a given duty, any number of tubes of a given length may be used with practically no effect on the total number of moles of HCl absorbed in the heat exchanger. This holds true over wide limits. In any event, the maximum number of tubes is fixed by the minimum liquid flow rate which will wet all the tube surfaces, 20 lb./hr. for ⅞-in I.D. tubes, proportionately for other diameters. To increase the portion of entering HCl absorbed in the heat exchanger, the length of the tubes must be increased.

Assuming that the operator of the impervious graphite falling-film absorber in Figure 4 wanted to produce no less than 31% acid, one can see that 31 ⅞-in I.D. tubes was the best absorber size for a gas flow ranging from 350 to 1,700 lb./hr. The next smallest standard absorber, 19 ⅞-in. I.D. tubes could not produce 31% acid at 1,700 lb./hr. gas flow. The next larger standard absorber 42 ⅞-in. I.D. tubes, might not produce 31% acid at 350 lb./hr. gas flow because some tubes might be only partially wet with liquid.

Conventional design practices are employed to compute the required cross-sectional area in the tail gas scrubber for the gas and liquid flows used. The tail gas scrubber must handle all the inert gases plus one-third of the HCl gas fed to the system if water is used as the absorbing liquid. If 20% acid is fed to the system, the tail gas scrubber will have to handle only one-fourth of the HCl in the feed gas plus the inert gases. In line with data of Oldershaw, *et al.* (7), the minimum HTU required in a packed tail gas scrubber has been found to be 1.5. However, it is customary to provide 2-3 *H.T.U.* to allow for gas surges and to reduce vent losses to a minimum.

Pressure Drop

Measurements of pressure drops across the heat exchangers of falling-film systems have shown that the pressure drops with and without liquor flow are almost identical. This permits use of conventional heat exchanger pressure drop calculations. In the case of concentrated gases, the mass velocity of the gas decreases appreciably between the top and bottom of the tubes in the heat exchanger. Following the convention for condensers where the problem is similar, base the calculation on the inlet mass velocity. For concentrated gases, multiply the result by 0.6, and for dilute gases, by 1.0.

Falling-Film Systems

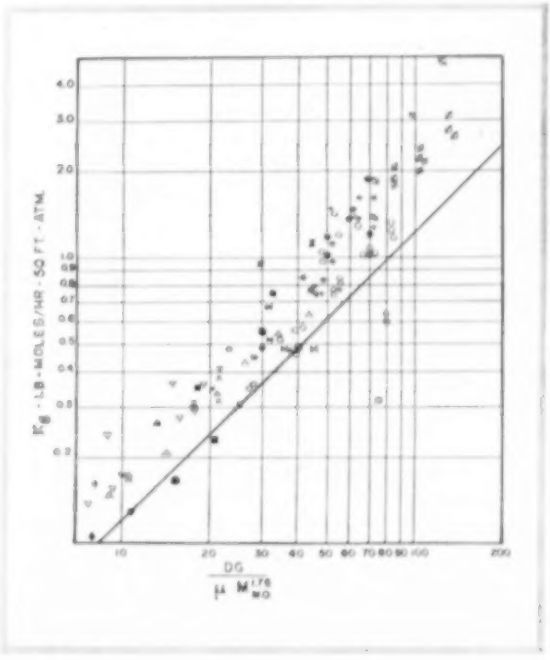
FOR DILUTE GASES

Most HCl gas streams fed to commercial absorption equipment contain more than 40% HCl by volume. This, coupled with the requirement that the heat exchanger remove only two-thirds or one-quarter of the HCl in the gas stream, enables the basic system in Figure 7 to produce acid nearly as concentrated as a theoretical countercurrent absorber. For dilute feed gases, the product acid from a system of the type in Figure 7 would be limited to a vapor pressure about one-third that of the HCl in the gas feed. To enable a closer approach of the product acid

Fig. 5. Mass transfer rates in falling-film hydrochloric acid absorbers.

KEY TO FIGURE 5

Symbol	Vol. % HCl at inlet	Mole wt. inert gas	I.D. tube in.	Tube length ft.	Number of tubes
●	60	125	⅞	12	163
⋇	100	29	⅞	9	128
▲	49	134	⅞	12	85
◆	97.5	71	⅞	9	84
□	40	28	⅞	9	6
△	100	29	⅞	9	31
◇	100	29	⅞	9	139
▽	35-77	29	⅞	9	163
■	64-65	71	⅞	9	235
⧖	56	29	⅞	9	235
×	95	2	⅞	9	31
+	94-99	29	1½	9	1
⋈	39-42	29	1½	9	60
++	31-100	29	⅞	9	1
▼	55	128	⅞	9	128
○	83	29	1½	9	1
⌀	83	29	1	6	1
⌀	83	29	⅝	11.9	1
⧗	70	71	⅝	9	3
⋈	84	61	⅝	9	6
●	84	61	⅝	9	8



partial pressure to the feed gas, an additional heat exchanger is provided, as shown in Figure 1. In a certain sense, the system in Figure 1 is countercurrent. The HCl gas introduced to the lower exchanger progresses upward to the upper exchanger thence to the tail gas scrubber, countercurrent to the absorbing liquid feed to the top of the tail gas scrubber.

A system similar to that in Figure 1 is being constructed to produce 31.5% acid from feed gas at atmospheric pressure containing only 11% HCl by volume with cooling water at 85° F. The heat exchangers employ 2-in. I.D. tubes, 16 ft. long, to reduce the pressure drop and provide adequate mass transfer surface. In this installation, the gas flow will vary fourfold. In order to wet the tower packing and exchanger tubes at the low gas rates, acid is to be recirculated over the top of the tail gas scrubber. One of the reasons for selecting the falling film is that the initial cost is less than that for systems not having exchangers providing simultaneous mass and heat transfer.

When absorption of only 90-99% of the available HCl gas is economically justified, a system such as shown in Figure 1 with the tail gas scrubber omitted can be employed to advantage. Omission of a packed tower in the system will permit the pair of heat exchangers to handle a wider range of gas flows at a lower cost than a system comprised of a single exchanger and bubble-cap-type tail gas scrubber. Typical data on such a system are shown in Figure 8.

FOR PRESSURE OPERATION

A system such as Figure 8 also appears to be preferable for gases at several atmospheres pressure. All Karbate impervious graphite shell-and-tube heat exchangers to be used as absorbers are rated at 75 lb./sq.in. gauge working pressure. Calculations show that the Figure 8 system can produce 36% acid with 90° F. cooling water from a 75 lb./sq.in. gauge gas analyzing 10% HCl by volume with only 1% loss of HCl. A third exchanger would reduce this loss to a negligible value.

INSTRUMENTATION FOR FALLING-FILM ABSORBERS

Because of the corrosiveness and maintenance associated with hydrochloric acid, most installations are provided with a minimum of instruments. The recommended minimum includes a flow-rate indicator for the absorbing liquid, a specific gravity and temperature indicator for the product acid, and an indicator of the temperature of the acid leaving the tail gas scrubber.

In the usual falling-film system employing a tail gas scrubber, the most dependable method of automatically proportioning the feed liquid to gas is a temperature controller on the acid leaving the tail gas scrubber (*1, 3*). A simple, wide proportional band temperature controller works best for systems with low-capacity lag. Incorporation of derivative action in the controller is of value for installations with large lag.

Weak acid temperature control tends to maintain a constant product acid concentration regardless of load changes, provided automatic reset action is not being used. Automatic reset action is not usually recommended because it is desirable to allow the temperature of the acid leaving the tail gas scrubber to increase as the gas flow to the system increases.

It has been found that the hysteresis present to a degree in all pneumatic valves will cause cycling of the liquid feed flow rate and, accordingly, fluctuations in the concentration of the product acid. A valve positioner installed on a pneumatic motor valve will remove the hysteresis effect. The type of flow-lift characteristics obtained by equal-percentage disks is preferred to the characteristics other valve constructions give.

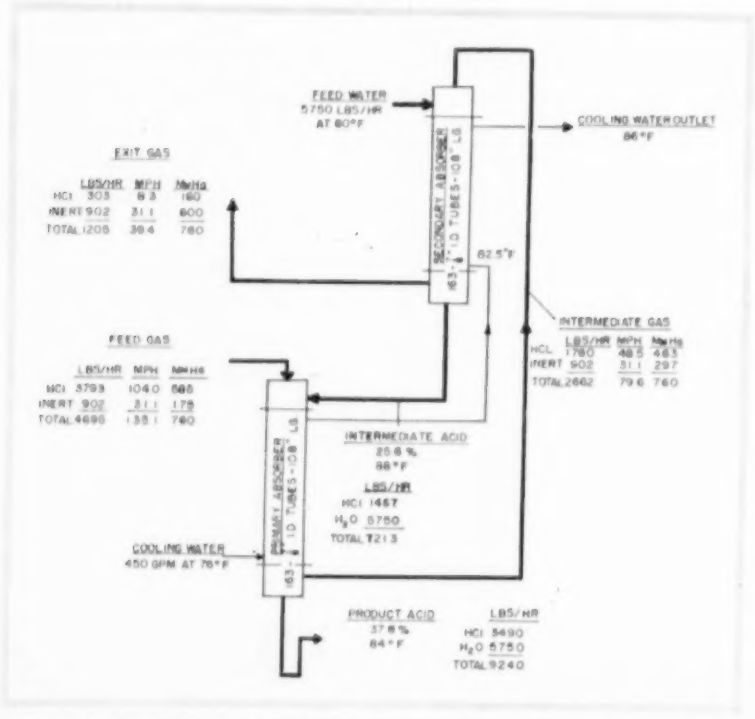


Fig. 8. Typical performance of "Karbate" falling-film absorber without tail gas scrubber.

Notation

- A = area, sq.ft.
- D = diam., ft.
- D_v = diffusivity, sq.ft./hr.
- G = mass velocity of gas lb./(hr.)(sq.ft.)
- K_g = over-all mass-transfer coefficient, lb. moles/(hr.)(sq.ft.)(atm.)
- L = mass velocity of liquid, lb./(hr.)(sq. ft.)
- M = molecular weight of gas stream
- N = number of moles
- P = pressure, atm.
- R = gas constant (cu.ft.)(atm.)/(lb. mole)(° R.) = 0.728
- T = abs. temp., ° R.
- HTU = height of one transfer unit, ft.
- ρ = density, (lb.)/(cu.ft.)
- μ = viscosity, (lb.)/(hr.)(ft.)
- ΔP_{am} = arithmetic-mean vapor pressure HCl, atm.

Subscripts:

- A = HCl
- B = inert gases
- m = mean
- o = inlet of tube
- t = outlet of tube

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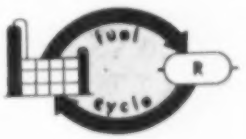
THERMAL REACTORS



The first part of this paper appeared on pages 96–F through 104–F of the February issue. It contained a qualitative description of the factors limiting the extent to which nuclear fuel can be utilized per pass through a nuclear reactor and developed quantitative methods for predicting changes in fuel composition and reactivity in nuclear reactors. It applied these methods to predicting the extent of fuel utilization in single-region, thermal reactors operating on the uranium-plutonium cycle with unmixed fuel.

FUEL CYCLES IN SINGLE-REGION THERMAL REACTORS

(Part 2)

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9. Mixed Fuel

In fluid-fuel reactors, such as the aqueous homogeneous reactor, the fuel is so well mixed that its composition is uniform throughout the reactor. In such reactors batch irradiation leads to exactly the same relationships as have been derived for unmixed fuel in Sections 7 and 8. An important advantage of fluid-fuel reactors, however, is their adaptability to continuous processing. In continuous processing of mixed fuel, the relationships describing fuel cycles are entirely different from those for unmixed fuel, because fresh fuel is being mixed continuously with reactor contents instead of being fed at one face of the reactor while spent fuel is being discharged at the other.

It is difficult to give a brief and complete account of continuous processing of mixed-fuel reactors, because some components of the fuel can be reprocessed more frequently than others; e.g., fuel can be processed frequently for fission-product removal and less frequently for plutonium. Instead of a general analysis of mixed-fuel processing, only cases which can be compared directly with the unmixed-fuel cases discussed earlier will be treated. In the reactor to be considered, reprocessing of plutonium, uranium, and fission products is to take place at the same frequency. The reactor has a single active region fueled with natural or slightly enriched uranium. To permit direct comparison with cases previously considered, it is to have the same neutron balance as has been given in the first column of Table 4. A practical example of this mixed-fuel case might be a reactor fueled with a slurry of uranium oxide in heavy water, with a portion of the slurry drawn off continuously for removal of fission products and uranium and recovery of plutonium, with possible recycle of this last metal to the reactor.

In Figure 11, the results of this analysis of continuous irradiation of mixed fuel are compared with those for continuous irradiation of unmixed fuel given in Sections 7 and 8. This figure shows the relationship between feed enrichment ratio and burn-up fraction. Curves (1) and (2) refer to cases in which plutonium is not recycled, curves (3) and (4) to plutonium-recycle cases. In each comparison, mixing of fuel limits the burn-up fraction that can be achieved with a given feed enrichment ratio to a much lower value than does unmixed fuel. The impaired performance of the mixed-fuel cases is due to the fact that fresh fuel is mixed with reactor contents and some fresh fuel is therefore withdrawn with spent fuel before it has been fully utilized. In the unmixed-fuel case the only material withdrawn from the reactor is fully depleted spent fuel.

Derivation of the relationships from which these results for mixed fuel were calculated is given by Benedict and Pigford (*1*). In this paper all that will be given is an outline of the method of derivation and the final equations.

The operating reactor is assumed to contain as well-mixed inventory I_{25} g. atoms of U^{235}, I_{28} g. atoms of U^{238}, I_F g. atoms of fission-product pairs, etc. The total inventory is I:

$$I = I_{25} + I_{28} + I_F + \cdots \qquad (48)$$

One "gram atom" of fission-product pairs consists of 2 g. atoms of fission products; this convention is used so that the total number of gram atoms in the reactor may be treated as constant as the fission reaction proceeds.

Uranium feed is supplied at the rate of F_t^0 g. atoms/sec., with F_{25}^0 and

F_{28}^0 being the feed rates for U^{235} and U^{238} respectively. Because of the assumption that the fuel is well mixed, the fraction f of the reactor inventory removed per unit time in the slurry leaving the reactor is the same for every nuclide in the reactor. The flow rate F_i of each component in the reactor product is then proportional to the reactor inventory of that component:

$$\frac{F_{25}}{I_{25}} = \frac{F_{26}}{I_{26}} = \frac{F_{28}}{I_{28}} = \frac{F_U}{I_U} = \frac{F_{Pu}}{I_{Pu}} = \ldots = \frac{F_F}{I_F} = \frac{F}{I} = f = \frac{1}{T} \quad (49)$$

The fractional processing rate, f, is the reciprocal of the average time T that a volume of fuel slurry is exposed to neutrons in the reactor before it is removed as product.

It is assumed that the reactor and its fuel-processing system have come to steady state with all flow rates and inventories independent of time and that the reactor is in neutron balance. It is also assumed that a reference design is known, in which the reactor contains only U^{235} and U^{238} in amounts I_{25}^* and I_{28}^* and is in neutron balance.

Uranium-235

The feed rate of U^{235} equals the sum of its rate of reaction with neutrons and its rate of removal from the reactor:

$$F_{25}^0 = \sigma_{25}\phi I_{25} + F_{25} \quad (50)$$

where ϕ is the average flux of neutrons in the reactor, and σ_{25} is the effective cross section for absorption of neutrons in U^{235}. This material-balance relationship is a simple algebraic equation instead of the differential equation (10) met in the unmixed-fuel case. Since $F_{25} = I_{25}/T$

$$I_{25} = \frac{F_{25}^0 T}{1 + \sigma_{25}\phi T} \quad (51)$$

For the mixed-fuel case, the average flux time τ of irradiation may be defined as

$$\tau = \phi T \quad (52)$$

and so this relation between the U^{235} inventory and flow rate is

$$I_{25} = \frac{F_{25}^0 T}{1 + \sigma_{25}\tau} \quad (53)$$

Uranium-236

The material-balance equation for U^{236} is as follows:

$$\frac{a_{25}\sigma_{25}\phi I_{25}}{1 + a_{25}} = \sigma_{26}\phi I_{26} + F_{26} \quad (54)$$

Since

$$F_{26} = \frac{I_{26}}{T} \quad (55)$$

one may solve for I_{26}:

$$I_{26} = \frac{a_{25}\sigma_{25}\tau}{(1 + \sigma_{26}\tau)} \frac{F_{25}^0 T}{(1 + \sigma_{25}\tau)(1 + a_{25})} \quad (56)$$

Uranium-237

Uranium-237 is radioactive, with a half-life of 6.75 days, and its concentration in secular equilibrium with irradiated fuel is relatively small. The effects of U^{237} and its decay product Np^{237} are neglected.

Uranium-238

In the present case, in which the reactor fuel is predominantly U^{238}, depletion of U^{238} is at most only a few per cent. To keep the equations from becoming unnecessarily complicated, depletion of U^{238} is neglected so that F_{28} may be assumed equal to F_{28}^0. Then

$$I_{28} = F_{28}^0 T \quad (57)$$

Plutonium-239

The material-balance equation for Pu^{239} is

Production

$\sigma_{28}\phi I_{28}$ thermal absorption in U^{238} + $\sigma_{25}\phi\eta_{25}\epsilon P_1(1-p)I_{25}$ resonance absorption of fast neutrons produced by U^{235} fission + $\sigma_{49}\phi\eta_{49}\epsilon P_1(1-p)I_{49}$ resonance absorption of fast neutrons produced by Pu^{239} fission

$=$

Removal

$\sigma_{49}\phi I_{49}$ thermal absorption in Pu^{239} + F_{49} drawn off as reactor product

(58)

Production of Pu^{239} from neutrons generated by Pu^{241} fission is neglected in the preceding equation, because if no plutonium is recycled, Pu^{241} will not be present in sufficient quantity to affect the Pu^{239} concentration.

Since

$$F_{49} = \frac{I_{49}}{T} \quad (59)$$

Equation (59) may be solved for I_{49} in terms of $F_{25}^0 T$ and $F_{28}^0 T$:

$$I_{49} = \frac{F_{28}^0 T\sigma_{28}\tau + \dfrac{F_{25}^0 T\sigma_{25}\tau\eta_{25}\epsilon P_1(1-p)}{1 + \sigma_{25}\tau}}{1 + \sigma_{49}\gamma\tau} \quad (60)$$

where γ is given by Equation (17).

By continuation of this analysis, equations for I_{40}, I_{41}, and I_F may be obtained. All are linear functions of $F_{28}^0 T$ and $F_{25}^0 T$, with coefficients functions of flux-time, τ.

The excess reactivity for a mixed-fuel reactor is expressed by an equation similar to (8), with the inventory of each component, I_i, replacing the average concentration, N_i, and the inventory of U^{235} in the reference design I_{25}^* replacing the concentration N_f^*. Since each inventory is a linear function of $F_{25}^0 T$ and $F_{28}^0 T$, the excess reactivity is also. At the maximum flux-time at which the mixed-fuel case is operable, the excess reactivity drops to zero. Under this condition the equation for the excess reactivity can be solved for $F_{25}^0 T$. The feed enrichment ratio for the mixed-fuel case is defined as

$$R = \frac{F_{25}^0/F_{28}^0}{I_{25}^*/I_{28}^*} \quad (61)$$

It is assumed that the U^{238} inventory in the reference design and in the operating reactor is the same, and so

$$I_{28}^* = I_{28} = F_{28}^0 T \quad (62)$$

With this assumption

$$R = F_{25}^0 T/I_{25}^* \quad (63)$$

It is thus possible to evaluate R from the condition that the excess reactivity equals zero at a stated flux-time.

The burn-up fraction, β, for the mixed-fuel case is obtained as the ratio of the rate of discharge of fission-product pairs F_F to the total feed rate, $F_{25}^0 + F_{28}^0$:

$$\beta = \frac{F_F}{F_{25}^0 + F_{28}^0} \quad (64)$$

By substitution of

$$F_F = I_F T \quad (65)$$

and the use of (62) and (63), an equivalent expression for β is obtained:

$$\beta = \frac{I_F/I_{28}^*}{1 + RI_{25}^*/I_{28}^*} \qquad (66)$$

This equation permits evaluation of β as a function of R and the flux-time. Curve (1) of Figure 11 was obtained by plotting R from (63) against β from (66).

The plutonium-recycle case is treated in similar fashion, except that in material-balance equations for plutonium the flow term such as F_{49} in Equation (58) is dropped.

10. Flowsheets for Uranium-plutonium Fuel Cycles

A process flowsheet for the sodium-graphite reactor example operating with no recycle is shown in Figure 12, and a similar flowsheet for plutonium recycle is shown in Figure 13. In each case the reactor is assumed to operate with continuous irradiation of unmixed fuel, the maximum burn-up being limited by the neutron-balance considerations developed in this paper. When plutonium is recycled (Figure 13), the reactor is assumed to operate on natural-uranium feed. When plutonium is not recycled (Figure 12), the feed enrichment was chosen to give approximately the same fractional burn-up of uranium feed as for the plutonium-recycle illustration. A heat-generation rate of 1,000 Mw. is assumed for each case, and the values of concentrations and burn-up obtained from the equations of this paper have been adjusted to allow for U^{238} depletion.

In Figure 12, flow of natural uranium to the isotope-separation plant is based upon an assumed atom fraction of 0.0036 for U^{235} in the depleted uranium. The required feed rate of natural uranium to the nonrecycle process is roughly twice that to the plutonium-recycle case.

11. Fuel Costs

The choice of feed enrichment and resulting burn-up for a given reactor depends upon economic considerations, which are treated in this section, and on the limits set by radiation damage. The greater unit cost of the more highly enriched fuel required for high burn-up is offset by the smaller amount of fuel required per unit of energy produced, and for any fuel cycle there will be an optimum burn-up which results in least cost of fuel make-up, fabrication, and reprocessing. These costs, in mills (0.1¢) per kilowatt-hour of electricity produced, will be illustrated for the sodium-graphite reactor example as follows.

With Equation (35) the number of kilograms of uranium feed per kilo-

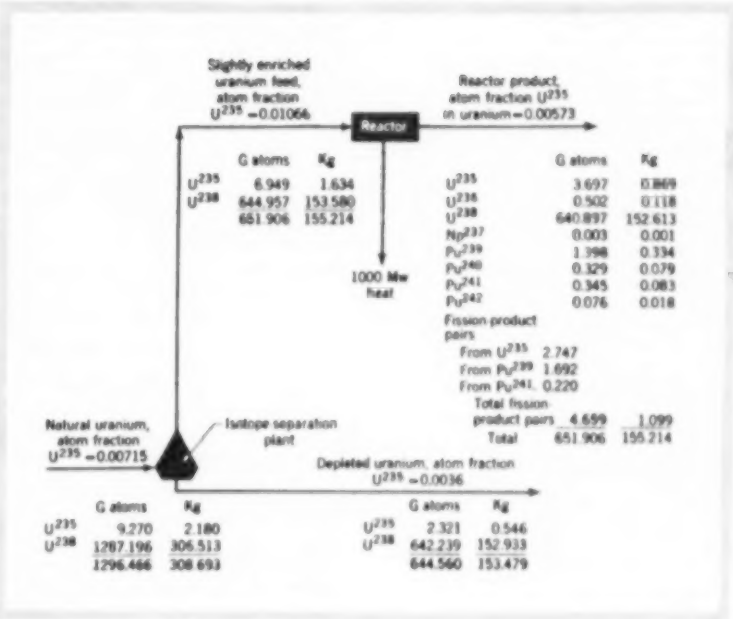

Fig. 12. Flowsheet for sodium-graphite reactor, no recycle. Continuous irradiation, $R = 1.067$, $\beta = 0.00715$. Exposure = 6,440 Mw. d./ton of uranium fed to reactor.

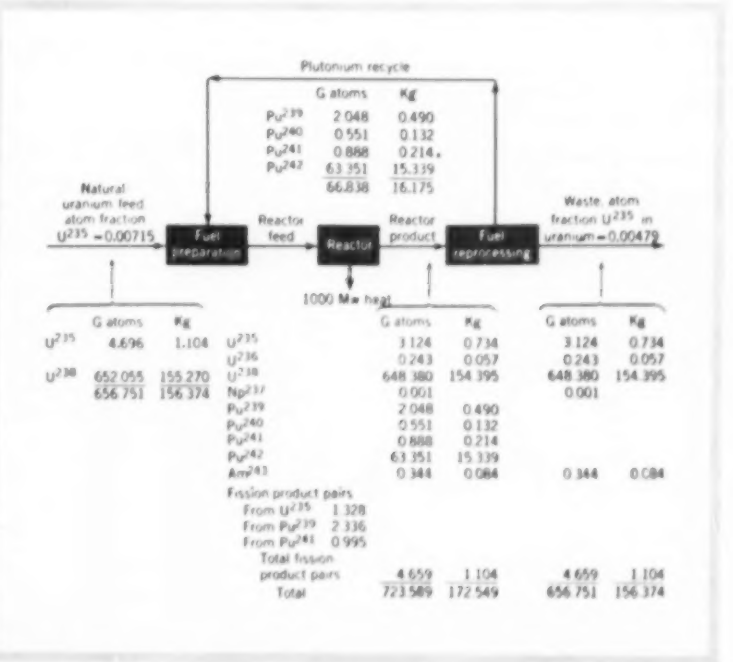

Fig. 13. Flowsheet for sodium-graphite reactor, plutonium recycle, natural uranium feed. Continuous irradiation, $\beta = 0.00709$. Exposure = 6,400 Mw. d./ton of uranium feed.

Table A

	Cost, $/kg. uranium
Cost of enriched uranium feed (as UF_6)	C_U^0
Value of uranium recovered from spent fuel, if returned to the isotope-separation plant (as UF_6)	C_U^7
Conversion of UF_6 to uranium metal	C_C
Fabrication of fuel elements	C_F
Reprocessing of spent fuel (including conversion of plutonium salts to metal)	C_R
Conversion of uranium salts to UF_6	C_H

watt-hour electrical, for an assumed 30% net thermal efficiency, is

$$\frac{\text{kg. uranium}}{\text{kw.-hr.}} = \frac{\text{ton}}{9.0 \times 10^5 \beta \text{ Mw.-d.}} \times \frac{\text{Mw.-d.}}{24 \times 10^3 \text{ kw.-hr.}} \times \frac{\text{kw.-hr.(heat)}}{0.30 \text{ kw.-hr.(elec.)}} \times \frac{10^3 \text{kg.}}{\text{ton}} = \frac{1.54 \times 10^{-7}}{\beta} \qquad (67)$$

The unit costs that must be specified to determine the total fuel cost are shown in the accompanying Table A. The unit cost, C_U, of enriched uranium, as UF_6, can be obtained (*1*) from Equation (*68*), which fits the cost schedule for enriched uranium announced in November, 1956, by the U. S. Atomic Energy Commission:

$$C_U \text{ (\$/kg. of contained U)} = 37.48 \left[(2X - 1) \ln \frac{449}{1 - X} + 449 (X - 0.00322) \right] \qquad (68)$$

where X is the weight fraction of U^{235} in uranium. The weight fraction X^0 of U^{235} in the feed is obtained from

$$X^0 = \frac{\frac{N_{25}^*}{N_{28}^*} R}{1 + \frac{N_{25}^*}{N_{28}^*} R} \qquad (69)$$

and the weight fraction X^7 of U^{235} in the irradiated uranium is obtained from

$$X^7 = \frac{\frac{N_{25}^*}{N_{28}^*} Re^{-a_m \tau}}{1 + \frac{N_{25}^*}{N_{28}^*} Re^{-a_m \tau}} \qquad (70)$$

In an estimation of the fuel costs for irradiation without plutonium recycle, it is assumed that the spent fuel is discarded, and so the fuel cost per unit of electrical energy is given by

$$\text{fuel cost (mills/kw.-hr.)} = 1.54 \times 10^{-4} \frac{C_U^0 + C_C + C_F}{\beta} \qquad (71)$$

Assigning costs of \$4/kg. for C_C and \$16/kg. for fabricating uranium fuel elements (C_F) and using the relationships of R and β for batch and continuous irradiation from Figure 8 gives the nonrecycle-fuel costs shown by curves (*1*) and (*2*) of Figure 14. The economic incentives in obtaining burn-up greater than 1% are apparent. No minimum fuel cost is reached for the range of burn-ups considered.

The unit costs assigned for plutonium recycle are as follows:

	\$/kg. Uranium
C_C	4
C_F	32
C_R	14
C_H	4

The assumed cost of fuel fabrication is higher in this case because of the extreme toxicity of plutonium. When the isotopic content of U^{235} in the depleted uranium is greater than about 0.34% (where $C_U^7 = C_H$), it will be economical to recover uranium for reenrichment, and under these conditions the plutonium-recycle fuel cost is obtained from

$$\text{fuel cost (mills/kw.-hr.)} = 1.54 \times 10^{-4} \frac{C_U^0 + C_C + C_F + C_R + C_H - C_U^7}{\beta} \qquad (72)$$

The fuel costs for enrichments of U^{235} in the spent fuel lower than 0.34% are obtained by eliminating C_H and C_U^7 from Equation (*72*). For the particular case of natural uranium feed, C_C is eliminated.

Fuel costs for the sodium-graphite reactor operating with plutonium recycle are shown by curves (*3*) and (*4*) in Figure 14. It is apparent that in spite of the higher unit processing costs associated with recycle operation, the lower unit cost of make-up fuel and the credit for depleted uranium result in lower net fuel cost per unit of energy than for the simpler once-through cycle.

12. Thorium-U^{233} System

REACTOR SYSTEM CONSIDERED

This section is concerned with a single-region thermal breeder reactor, fueled with a mixture of thorium and U^{233} and operated as shown in the fuel-reprocessing flowsheet of Figure *2*. The reference design of a reactor of the sodium-graphite type for this fuel has been given in the second column of Table *2*, and the neutron balance for the reference design of this reactor has been given in the second column of Table 4.

The primary objective of the following discussion is to determine the fractional burn-up that can be achieved in each pass of fuel through the reactor without any fissionable material from an outside source, when make-up fuel consists only of thorium. The fact that the conversion ratio in the reference design, 1.0625, is greater than unity suggests that even after higher isotopes of U^{233} have built up in recycle operation, the conversion ratio will be high enough to permit operation at finite burn-up on pure thorium make-up fuel.

A reactor of this type would probably be started with a mixture of thorium and U^{235}, unless sufficient quantities of U^{233} produced in another reactor were available. As the reactor operates, each new fuel charge is fabricated from fresh thorium and U^{235}, blended with recycled thorium and U^{233}. As the U^{233} and its higher-mass uranium isotopes build up, the required amount of make-up U^{235} becomes smaller, and finally, after a number of irradiation cycles, only make-up thorium is required to keep the reactor in operation.

The reference design with U^{233}–thorium fuel does not necessarily represent the initial charge of the operating reactor, but serves to specify the nuclear properties of the reactor to be used in determining fuel composition during irradiation and neutron-balance requirements.

FUEL COMPOSITION AND IRRADIATION CHARACTERISTICS

The fuel composition and irradiation characteristics will be considered for the reactor in steady-state recycle operation. In the operating reactor the concentration of thorium is assumed to be equal to that in the reference design and the slight depletion of thorium during a single irradiation cycle will be neglected. After a number of cycles of irradiation, the concentration of the uranium isotopes U^{233}, U^{234}, U^{235}, and U^{236} will have reached steady-state values in the reactor feed. If time lags in decay of Th^{233} and Pa^{233} and neutron absorption in Pa^{233} are neglected, the concentrations of the uranium isotopes will be constant during the irradiation. These concentrations are obtained from the following material-balance equations:

Table 5.—Equilibrium Fuel Compositions for Sodium-graphite-thorium Reactor

	Atoms/atom of Th^{232}	Total gram atoms in reactor
U^{232}	0.0230	3,030
U^{234}	0.00338	443
U^{235}	0.001859	242
U^{236}	0.01654	2,160
Total	0.0448	5,875

$$U^{233}: N_{02}\sigma_{02}\phi + N_{23}\sigma_{23}\phi[\eta_{23}\epsilon P_1(1-p)-1] + N_{25}\sigma_{25}\eta_{25}\phi\epsilon P_1(1-p)=0 \quad (73)$$

$$U^{234}: \frac{N_{23}\sigma_{23}a_{23}\phi}{1+a_{23}} - N_{24}\sigma_{24}\phi = 0 \quad (74)$$

$$U^{235}: N_{24}\sigma_{24}\phi - N_{25}\sigma_{25}\phi = 0 \quad (75)$$

$$U^{236}: \frac{N_{25}a_{25}\sigma_{25}\phi}{1+a_{25}} - N_{26}\sigma_{26}\phi = 0 \quad (76)$$

Eliminating N_{24} and N_{25} from Equations (73), (74), and (75) yields

$$\frac{N_{23}}{N_{02}} = \frac{\sigma_{02}}{\sigma_{23}\zeta} \quad (77)$$

where

$$\zeta = 1 - \epsilon P_1(1-p)\left(\eta_{23} + \frac{a_{23}\eta_{25}}{1+a_{23}}\right) \quad (78)$$

From Equations (74) and (77)

$$\frac{N_{24}}{N_{02}} = \frac{\sigma_{02}a_{23}}{\sigma_{24}(1+a_{23})\zeta} \quad (79)$$

From Equations (75) and (79)

$$\frac{N_{25}}{N_{02}} = \frac{\sigma_{02}a_{23}}{\sigma_{25}(1+a_{23})\zeta} \quad (80)$$

From Equations (76) and (80)

$$\frac{N_{26}}{N_{02}} = \frac{\sigma_{02}a_{23}a_{25}}{\sigma_{26}(1+a_{23})(1+a_{25})\zeta} \quad (81)$$

The equilibrium concentrations in Table 5 are calculated for the sodium-graphite reactor example by means of data from Tables 3 and 4.

Because the fuel composition is constant, the concentrations $\Sigma_F N_F(23)$ of fission-product pairs from U^{233} fissions and $\Sigma_F N_F(25)$ from U^{235} fissions build up linearly with time t, or flux-time θ, according to

$$\Sigma_F N_F(23) = \frac{N_{23}\sigma_{23}\theta}{1+a_{23}} \quad (82)$$

and

$$\Sigma_F N_F(25) = \frac{N_{25}\sigma_{25}\theta}{1+a_{25}} \quad (83)$$

and the total concentration $\Sigma_F N_F$ of fission-product pairs is

$$\Sigma_F N_F = \Sigma_F N_F(23) + \Sigma_F N_F(25) \quad (84)$$

Combining equations gives

$$\frac{\Sigma_F N_F}{N_{02}} = \frac{\sigma_{02}(1+a_{23}+a_{25})\theta}{(1+a_{23})(1+a_{25})} \quad (85)$$

The average excess reactivity $\bar{\Delta}$ for the operating reactor is obtained by applying Equation (8):

$$\bar{\Delta} = \left(\frac{N_{23}}{N_{23}^*} - 1\right)(\eta_{23}\epsilon P'_{1h}p - 1) - \frac{N_{24}\sigma_{24}}{N_{23}^*\sigma_{23}} + \frac{N_{25}\sigma_{25}}{N_{23}^*\sigma_{23}}(\eta_{25}\epsilon P'_{1h}p - 1) - \frac{N_{26}\sigma_{26}}{N_{23}^*\sigma_{23}} - \frac{\Sigma_F N_F \sigma_F}{N_{23}^*\sigma_{23}} \quad (86)$$

Because all concentrations except $\Sigma_F N_F$ are time invariant, the excess reactivity will be initially greater than zero and will decrease linearly with flux-time as the irradiation proceeds, in a manner similar to the reactivity for plutonium recycle shown in Figure 10.

The maximum flux-time, τ, for batch irradiation is obtained by substituting Equations (77), (79), (80), (81), and (85) into (86) and setting $\bar{\Delta}$ equal to zero:

$$\tau = \frac{(1+a_{23})(1+a_{25})}{(1+a_{23}+a_{25})\sigma_F} \left[\left(1 - \frac{N_{23}^*\sigma_{23}\zeta}{N_{02}\sigma_{02}}\right)(\eta_{23}\epsilon P'_{1h}p - 1) + \frac{a_{23}}{1+a_{23}}\left(\eta_{25}\epsilon P'_{1h}p - 2 - \frac{a_{25}}{1+a_{25}}\right)\right] \quad (87)$$

The maximum flux-time, τ, for continuous irradiation is twice as great as that for batch irradiation calculated from Equation (87).

The burn-up fraction, β, defined here as the number of atoms fissioned during the irradiation per atom of thorium present at the beginning of the irradiation, is given by

$$\beta = \frac{\Sigma_F N_F(\tau)}{N_{02}} \quad (88)$$

Combining Equations (85) and (88) gives

$$\beta = \frac{\sigma_{02}(1+a_{23}+a_{25})\tau}{(1+a_{23})(1+a_{25})\zeta} \quad (89)$$

where τ is given by (87). The burn-up

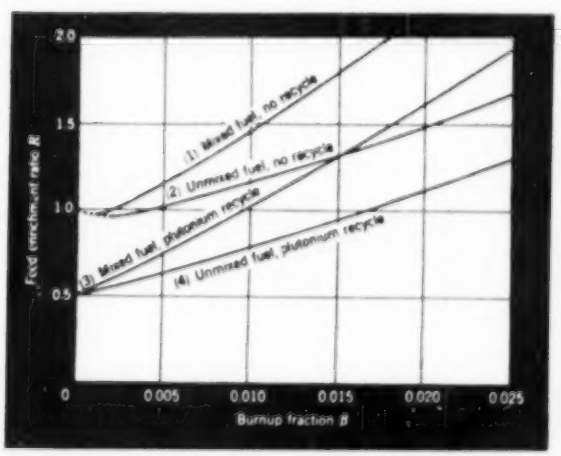

Fig. 11. Comparison of maximum burn-up for mixed and unmixed fuel, continuous irradiation.

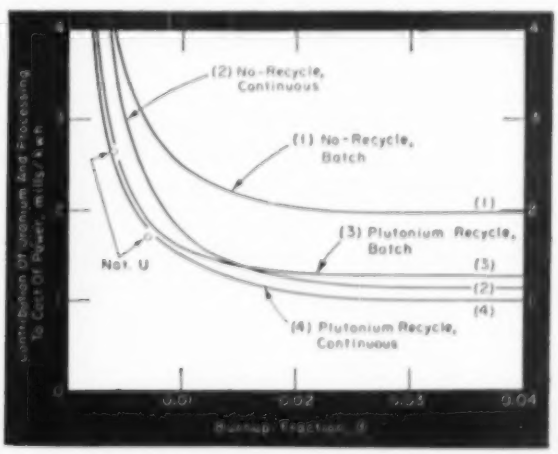

Fig. 14. Fuel costs vs. burn-up fraction.

Table 6.—Irradiation Characteristics of Sodium-graphite-thorium Reactor

	Batch irradiation	Continuous irradiation
Maximum flux-time, τ, cm.$^{-2}$	1.403×10^{23}	2.81×10^{23}
Maximum irradiation time at 1,000 Mw. days	307	614
Maximum fuel burn-up fraction, β (atoms fissioned/atom Th^{232} in fuel)	0.01089	0.0218
Heat exposure, Mw. d./ton of thorium	10,100	20,200

fraction for continuous irradiation is twice that for batch irradiation.

The irradiation time and burn-up for the illustrative sodium-graphite-thorium reactor calculated from the preceding equations are listed in Table 6. Heat exposures, calculated from Equation (34), are also listed.

MATERIAL FLOWSHEET FOR SINGLE-REGION THORIUM BREEDER

As shown above, the maximum irradiation time and fuel burn-up per cycle for a single-region thorium breeder operating with complete recycle of thorium and uranium in a particular irradiation scheme are determined uniquely by the nuclear properties of the reference design. A material flowsheet for the sodium-graphite reactor example operating as a thorium breeder with continuous irradiation is shown in Figure 15.

The fuel cost for the thorium-breeder example is estimated by using the A.E.C. figure of \$43/kg. for the cost of make-up thorium metal and assuming \$32/kg. for fuel fabrication, \$14/kg. for fuel reprocessing, and \$4/kg. for conversion of thorium salts to metal for refabrication. The fuel cost on this basis, for a net thermal efficiency of 30%, amounts to 0.37 mill/kw.-hr., of which only 0.007 mill is the cost due to make-up thorium.

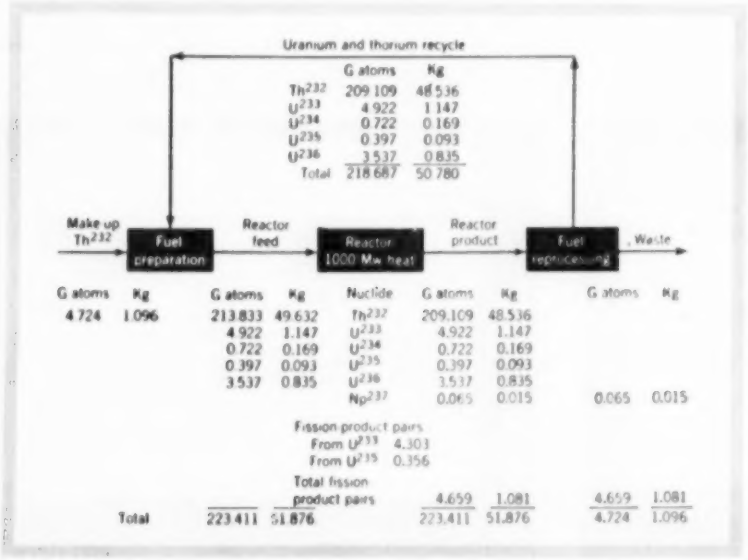

Fig. 15. Flowsheet for sodium-graphite-thorium reactor, uranium and thorium recycle. Continuous irradiation, $\beta = 0.0221$. Exposure: 20,200 Mw. d./ton of thorium per cycle.

Appendix A

EFFECTIVE CONCENTRATIONS IN VARIABLE-FLUX REACTOR WITH CONTINUOUS FLOW OF UNMIXED FEED

Considered here is an unreflected, single-region reactor shaped like a right prism or cylinder, in which flux varies with transverse coordinates x and y and longitudinal coordinates z as

$$\phi(x,y,z) = \psi(x,y) \sin \frac{\pi z}{L} \qquad (A1)$$

Fuel is moved through the reactor in the z direction at uniform velocity $u(x,y)$ so that when it has left the reactor a distance L from the charging face it will have been irradiated to a constant flux-time τ at all x and y. Since

$$\tau = \int_0^L \phi(x,y,z) \frac{dz}{u(x,y)} \qquad (A2)$$

it is necessary that $u(x,y)$ be given by

$$u(x,y) = \frac{2L}{\pi\tau} \psi(x,y) \qquad (A3)$$

Then the flux-time to which fuel at (x,y,z) has been exposed is

$$\theta(x,y,z) = \int_0^z \frac{\pi\tau}{2L} \sin \frac{\pi z'}{L} dz' = \frac{\tau}{2}\left(1 - \cos \frac{\pi z}{L}\right) \qquad (A4)$$

Flux-time thus depends only on distance z in the direction of movement of fuel and is independent of x and y. This situation is represented schematically in case (c) of Figure 4. Since N is a function of τ, which is a function of z only, the correct expression for $\bar{N}$ for this case, from Equation (7), is

$$\bar{N} = \frac{\int_0^L N\left[\frac{\tau}{2}\left(1 - \cos \frac{\pi z}{L}\right)\right] \sin^2 \frac{\pi z}{L} dz}{\int_0^L \sin^2 \frac{\pi z}{L} dz} \qquad (A5)$$

The general form for the dependence of concentration, N, on flux-time θ is

$$N = a + b\theta + \sum_i c_i e^{-\sigma_i \theta} \qquad (A6)$$

The result of substituting (A4) for θ, substituting (A6) into (A5), and carrying out the indicated integration is

$$N = a + \frac{b\tau}{2} + \sum_i c_i \frac{4e^{-\frac{\sigma_i\tau}{2}} I_1\left(\frac{\sigma_i\tau}{2}\right)}{\sigma_i\tau} \qquad (A7)$$

The last expression is a consequence of the fact that

$$\frac{\int_0^L e^{-\frac{\sigma_i\tau}{2}\left(1 - \cos \frac{\pi z}{L}\right)} \sin^2 \frac{\pi z}{L} dz}{\int_0^L \sin^2 \frac{\pi z}{L} dz} = \frac{4e^{-\frac{\sigma_i\tau}{2}} I_1\left(\frac{\sigma_i\tau}{2}\right)}{\sigma_i\tau} \qquad (A8)$$

as may be verified in any text on Bessel functions, e.g. reference 5. Thus, to obtain an expression for $\bar{N}$ from one for N the following substitutions should be made:

Constant term remains unchanged

θ is replaced by $\tau/2$

$e^{-\sigma\theta}$ is replaced by $4e^{-\frac{\sigma\tau}{2}} I_1\left(\frac{\sigma\tau}{2}\right)$

The first two substitutions are the same as when a simple average with respect to flux-time is taken. The last expression differs from $(1 - e^{-\sigma\tau})/\sigma\tau$ of the simple average. However, Table A-1 shows that the numerical result of using the exact expression

$$\frac{\left[4e^{-\frac{\sigma\tau}{2}} I_1\left(\frac{\sigma\tau}{2}\right)\right]}{\sigma\tau}$$

does not differ appreciably from the simpler expression $(1 - e^{-\sigma\tau})/\sigma\tau$ for value of $\sigma\tau$ below 2. This justifies the use of the simpler expression on page 102-F of Part I.

Table A-1

$\sigma\tau$	$\frac{1-e^{-\sigma\tau}}{\sigma\tau}$	$4e^{-\frac{\sigma\tau}{2}}\frac{I_1\left(\frac{\sigma\tau}{2}\right)}{\sigma\tau}$
0.0	1.000	1.000
0.5	0.790	0.785
1.0	0.633	0.624
1.5	0.518	0.506
2.0	0.432	0.415
3.0	0.317	0.292

Acknowledgment

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Notation

$\bar{A}$ = atomic weight of fuel
B^2 = geometric buckling, cm.$^{-2}$
C_c = cost of conversion of UF_4 to metal, \$/kg. U
C_f = cost of fuel fabrication, \$/kg. U
C_H = cost of conversion of uranium salts to UF_6, \$/kg. U
C_R = cost of reprocessing irradiated fuel, \$/kg. U
C_U = cost of enriched uranium (as UF_6), \$/kg. U
C_1 = defined by Equation (39)
C_2 = defined by Equation (38)
D = diffusion constant for thermal neutrons, cm.
E = specific energy yield, Mw.-d./metric ton
f = fraction of inventory removed from reactor/sec.
F = flow rate, g. atoms/sec.
I = inventory, g. atoms
L = length of reactor in direction of fuel movement, cm.
N = concentration, atoms/cc.
p = resonance escape probability
P_1 = nonleakage probability, fission to resonance energy
P_{1th} = nonleakage probability, fission to thermal energy
R = feed enrichment ratio, defined by Equation (31)
t = time after beginning of irradiation, sec.
T = avg. time fuel is left in reactor, sec.
u = velocity of fuel, cm./sec.
v = coefficient of N_m^0 in equation for atomic concentration
V = reactor vol., cc.
w = coefficient of N_{25}^0 in equation for atomic concentration
x,y = position coordinates in plane perpendicular to motion of fuel
X = weight fraction U^{235} in uranium
z = distance of fuel from charging face of reactor
α = ratio of capture cross section to fission cross section for fissionable nuclides
β = burn-up fraction, fraction of fuel make-up which is converted to heat
γ = defined by Equation (17)
Δ = local excess reactivity
$\bar{\Delta}$ = average excess reactivity
ϵ = fast fission factor, total fission neutrons produced per fission neutron from thermal fission
η = fission neutrons produced/thermal neutron absorbed in fissionable nuclides
ζ = defined by Equation (78)
θ = intermediate flux-time of irradiation, cm.$^{-2}$
ξ = defined by Equation (44)
σ = microscopic cross section for absorption of thermal neutrons, cm.$^{-2}$
τ = final flux-time of irradiation, cm.$^{-2}$
ϕ = thermal neutron flux, neutrons/(cm.^{2})(sec.)

ψ = transverse variation of flux, neutrons/(cm.^{2})(sec.)
ω = defined by Equation (45)

Superscripts

0 refers to condition at beginning of irradiation
* refers to property of reference design
τ refers to condition at end of irradiation

Subscripts

E means extraneous poisons used to control neutron balance
f means fissionable nuclides (for example U^{235}, Pu^{239}, Pu^{241}
F means fission products other than Xe^{135} and Sm^{149}
g means fertile nuclides (e.g., U^{238}, Th^{232}
h means higher mass isotopes resulting from nonfission capture of neutrons in fissionable nuclides
P means neutron absorbers in reactor due to structural material, coolant, and controls
Sm refers to samarium^{149}
Xe " " xenon^{135}
02 " " Th^{232}
23 " " U^{233}
24 " " U^{234}
25 " " U^{235}
26 " " U^{236}
28 " " U^{238}
49 " " Pu^{239}
40 " " Pu^{240}
41 " " Pu^{241}
42 " " Pu^{242}

TANKS FOR 1000 YEARS: design considerations of storage tanks for radioactive waste

At the Savannah River Plant, the separation of the desired components from irradiated materials results in the production of large volumes of high-level radioactive wastes. Fission products in the waste produce a level of radioactivity which is too high by a factor of 10^{10} to permit immediate discharge of the waste to the river, either by intent or by accident. Two of the fission products, strontium 90 and cesium 137, have half-lives of 20 years and 37 years, respectively, and even after twenty years, the level is still too high by a factor of 10^8 for discharge to the river.

The Alternatives

The problem of handling such wastes resolves itself to long-term storage, industrial use, or reclamation. Because of the high costs involved in attempting to use or reclaim materials in the wastes, they have been handled so far by storing in underground tanks. At the Savannah River Plant, a design for storage containers having unusual degrees of safety and reliability was demanded since it would take on the order of 1,000 years for the radioactive wastes to decay sufficiently to be harmless.

Design Factors

Main factors to be taken into account in the design were:

PROPERTIES OF THE WASTE

1. Volume—several million gallons
2. Radioactivity—intense
3. Corrosive properties—alkaline
4. Transport of waste—by pipeline as liquid containing no undissolved solids
5. Concentration—specific gravity about 1.2
6. Heat Release—estimated at 4 B.t.u./hr./gal.
7. Venting—vented air to contain particulate contamination.

TANK ENVIRONMENT

1. Population—settled areas within 25 to 30 miles of plant site.
2. Location—tank sites within 1500 feet of process building and at ten feet less elevation.
3. Soil Bearing—5000 lb./sq.ft.
4. Ground Water—25 to 30 feet below natural grade.

Tank Design

Analysis of the above factors led to a tank design which was used for the initial tanks constructed at Savannah River. After these first tanks had been completed, certain new information received from Hanford and gathered from laboratory studies at the Savannah River Plant itself indicated that a sludge could be expected to settle to the bottom as a heavy unmixed layer carrying with it about 90% of the

heat-producing radioactive elements. Estimates indicated that the temperatures in the sludge layer might reach 300° to 350° F. Although the tanks originally designed were adequate to contain wastes with this hot sludge layer, it was thought desirable in the new installation to increase the safety factor to compensate structurally for the increased temperature at the bottom of the tank.

The latest design incorporated the following components:

1. *Primary Container*—All steel shell with a diameter of 85 ft. and a height of 27 ft. Total capacity—1,070,000 gallons. Top and bottom were ½ in. thick. Cylindrical portion varied in thickness from ⅝ in. at the top to 7/8 in. at the knuckle. Tank located underground to provide shielding from the intense radiation.

2. *Secondary Container*—All steel saucer which, in the event of a leak in the primary container, would be capable of holding sufficient leakage to permit transfer of the tank contents to another tank 90 ft. in diameter by 5 ft. high, fabricated of ½ in. thick steel.

3. *Housing for Containers*—Reinforced concrete shell to protect the primary and secondary containers from soil pressure and exterior corrosion, to support the earth shielding, and to serve as a third barrier to the escape of wastes. Bottom slab 3 ft. 6 in. thick stepped to 5 ft. 4 in. at the center. Walls 2 ft. 9 in. thick. Top 3 ft. 9 in. thick.

4. *Auxiliaries*—Primary container equipped with cooling coils to prevent release of airborne contamination. Instrumentation provided to monitor temperatures and volume in the tanks and to detect any leakage from the primary container. Filter on tank vent to prevent release of particulate contamination to the atmosphere.

Further Study Needed

During the course of design of the two installations, progress was made in reducing the cost of such facilities. A fertile field remains in the study of methods for reducing the volume of wastes to be stored and for reducing further the cost of the storage containers. Better solutions of one problem may lead to better solution of the other. For example, isolation of Strontium 90 and Cesium 137 would permit a large volume reduction in the remainder of the wastes. Removal of sufficient water from the wastes so that they would be in solid rather than liquid form would permit major reductions in the total and unit costs of waste containers.

A second possibility would involve aging the wastes in the tanks described until the heat evolution from radioactivity will have decreased to a point where the waste could be concentrated to a solid state although remaining fluid for transport at high temperatures. This would reduce volumes and simplify the final storage containers. Complete isolation of fission products, either in a solid state or in solution, would permit both volume reduction and container simplification. Much additional study is needed to supply a safe, reliable, and truly economic solution to the problem of radioactive waste disposal.

Condensed from a paper, "Design Considerations of Storage Tanks for Radioactive Wastes," by Edgar E. Wilson, Du Pont, presented at the Cleveland Nuclear Engineering and Science Congress.

RADIANT DESIGN OF HIGH TEMPERATURE HEATERS

Recently I became interested in the article by *L. J. McCarthy* on "Radiant Design of High Temperature Heaters," *CEP* Vol. **52**, No. 3, pp. 97M-104M (March, 1956).

For furnaces of Type C and D the following equation is given:

$$Re = 1400\left(\frac{H\times 10^{-3}}{a_c Acp}\right)^{1.13}\left(\frac{H\times 10^{-4}}{W}\right)^{0.60}$$

If I have correctly understood the meaning of the various terms, one can rewrite the left-hand side of the equation so that

$$\frac{eH\times 10^{-3}}{a_c Acp} = 1400\left(\frac{H\times 10^{-3}}{a_c Acp}\right)^{1.13}\left(\frac{H\times 10^{-4}}{W}\right)^{0.60}$$

where e is the per cent heat release absorbed in the radiant section. Note that the radiant receiving area appears on the left hand side in the denominator to the first order and on the right hand side to the 1.13 order. Suppose we try to approximate a quick design of a new furnace with this equation. Mathematically we find that if we maintain constant heat release and increase the radiant receiving area, e has to decrease—in other words, the paradoxical conclusion that with increasing radiant area less total heat is absorbed!

I would appreciate your comments.

D. E. Gelbin,
VEB Leuna-Werke,
Leuna Kr. Merseburg, Germany

With reference to the letter from Mr. Gelbin concerning equations 4 and 5 in my article, "Radiant Design of High Temperature Heaters," the point which Mr. Gelbin raises is a valid one, and converting the equation from its present form (in which one solves directly for rate of heat transfer) to a form in which one solves for per cent or fraction of heat absorbed, gives what appears to be an absurd result.

However, this is, of course, an empirical equation, and in its present form its use gives results correct within the limitations of the data from which it was developed.

Along the lines of Mr. Gelbin's analysis, a simple calculation will show the following:

If $Re = E\dfrac{H}{a_c Acp} = 1400\left(\dfrac{H\times 10^{-3}}{a_c Acp}\right)^{1.13}\left(\dfrac{H\times 10^{-4}}{W}\right)$ (1)

Where E = the per cent heat release absorbed in radiant section or,

$$EH(a_c Acp)^{0.13} = 1400\,(H\times 10^{-3})^{1.13}\left(\frac{H\times 10^{-4}}{W}\right)$$

If H and W were constant,

$$E(a_c Acp)^{0.13} = \text{constant} = C_1$$

On increasing surface by 50%, let E' be the new per cent heat release absorbed:

$$E'(1.5a_c Acp)^{0.13} = C_1 = E(a_c Acp)^{0.13}$$

$$\text{or } E' = \frac{E}{(1.5)^{0.13}} = \frac{E}{1.054} = 0.947E$$

Thus increasing $a_c ACp$ by 50% decreases E by 5.3%. Even though this statement is mathematically correct, this change is insignificant if we consider the fact that the fit of the data is good only with a plus or minus 5 per cent margin. This illustrates that paradoxical conclusions can be obtained from extrapolation of empirical equations. A statistical analysis of the above fit [Equation (1)] gave a spread of 9.6% in the value of Re for the data obtained.

At the same time, however, Re, the heat transfer rate [in Equation (1) below], would fall to 0.633 Re if $a_c Acp$ or equivalent surface area were raised by 50%:

$$Re = \left(\frac{H \times 10^{-3}}{a.Acp}\right)^{1.13} \left(\frac{H \times 10^{-4}}{W}\right)$$

$$= \frac{\text{constant}}{(a.Acp)^{1.13}}$$

if H & W are constant

$$Re' = \frac{\text{constant}}{(1.5\ a.Acp)^{1.13}}$$

$$= \frac{\text{Constant}}{1.58\ (a.Acp)^{1.13}} = 0.633\ Re$$

This is a rational result.

In the appendix of my paper, the advantages of working with heat transfer rate rather than fraction or per cent absorbed are discussed, and I believe the present instance is a confirmation of this point.

It is true, no doubt, that the constant 1.13 used in the equation would (if error in data were minimized) be less than 1.0; nevertheless, a graphical fit of the data leads to the constant 1.13 as used in the equation.

It should be noted that the heat receiving surface as used in the equation is the equivalent cold plane as developed by Hottel. Therefore the inconsistency of this constant could result either from inaccuracy of test data from which the equation was developed, limitations in the accuracy of determining the equivalent cold plane, or a combination of both.

Furnace Number	External Tube Area Square Feet	Effective Tube Area Square Feet a Acp
3	2945	2255
5	4443	2303
13	5780	2108
14	5780	2108
15	2890	1928
16	5780	2108

The accompanying table gives the external tube area and effective cold plane area of these heaters, and considering the wide variation in external tube area, the values for $a.Acp$ remain remarkably constant.

It would appear that translation of external tube area to effective tube area $a.Acp$ could cause the discrepancy in the present case. For example, it would require only a slight change of approximately 5 per cent (or in the order of 100 square feet) in the effective tube area of certain of the heaters in question to reduce the exponent 1.13 to a value of unity.

L. J. McCarthy

CORRELATIONS OF DISPERSION INTERFACIAL AREA WITH WEBER NUMBER

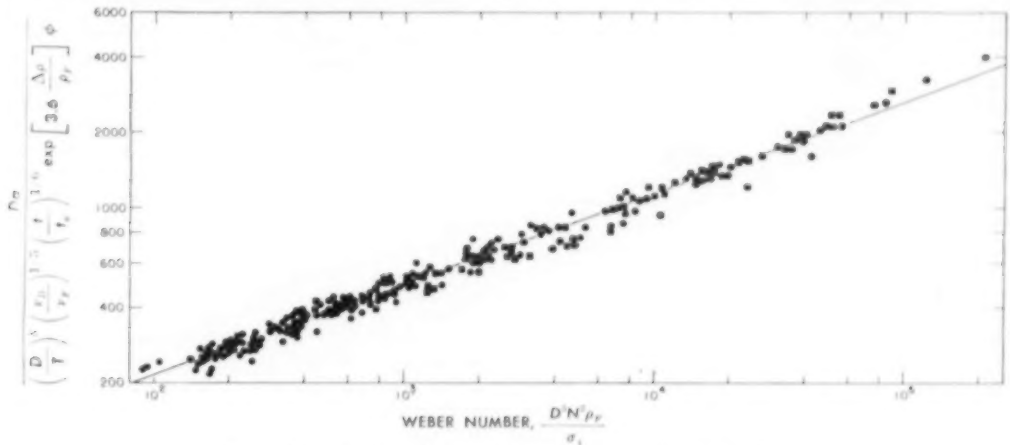


Fig. 6. Generalized correlation of interfacial area with Weber number.

In December, 1956 *CEP*, the paper "Effect of Fluid Motion on Inter-Facial Area of Dispersions," by W. A. Rodger, V. G. Trice, Jr., and J. H. Rushton, carried poor typographical reproductions of figures 6 and 7. These figures are reproduced again herewith.

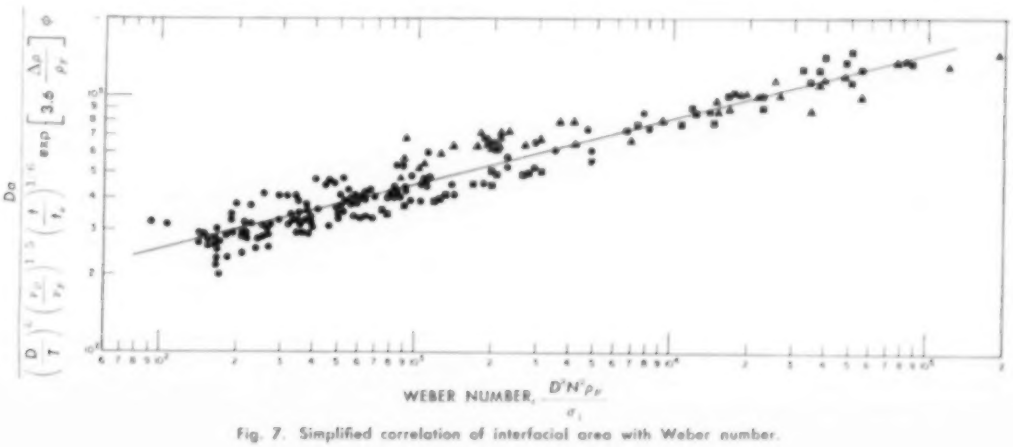


Fig. 7. Simplified correlation of interfacial area with Weber number.

how control over SO_2 EMISSION reduces AIR CONTAMINATION

A. R. Dudley | Humble Oil & Refining Company
Technical Service Division
Baytown, Texas

Combatting air pollution is an ever-present concern of the chemical engineer. A contamination reduction program initiated by Humble Oil has resulted in benefits which are described in the accompanying article.

Since the end of World War II, people living in industrial communities have become more concerned about air pollution. Humble Oil and Refining Company recognized this concern and in recent years has initiated an extensive program at its Baytown refinery to reduce the amount of contaminants released to the atmosphere. The major phase of this program is the reduction of sulfur dioxide contamination.

Figure 1 shows some sources of SO_2 contamination which existed at the refinery before the contamination reduction program was initiated; it shows also the sulfuric acid flow existing at that time. Black 98% acid was used as a catalyst at the alkylation plant. It was used also as a treating agent for lube distillates, lube residuum, and aromatic solvents. From each of these operations a spent acid was produced. A portion of the spent alkylation acid was used to treat gasoline, heating oil, and solvents.

Recovering Acid

Spent acids from these operations, together with the excess spent alkylation acid and the spent acids from treatment of lube distillates, were processed to recover as much of the contained acid as possible. This processing consisted first of agitating the spent acid with hot water in order to hydrolyze the sulfuric acid-hydrocarbon esters present. From this step, a weak acid phase and a hydrocarbon phase containing 15 to 25 wt. % unrecovered sulfuric acid were drawn. The weak acid from hydrolysis was charged to acid concentrators where sufficient water was removed to yield a product of about 85% acidity. This concentrated acid was barged to Houston where Consolidated Chemical Industries fortified it with SO_3 to 98% acidity. The fortified acid was then barged back to Baytown to complete the cycle.

It was not feasible to hydrolyze the spent acid from the treatment of lube residuums because the carbon contained in the fortified acid acted as an emulsifying agent in the hydrolysis operation. Similarly, it was not possible to hydrolyze the spent acid from the treatment of aromatic solvents due to high solubility of the hydrocarbons in the aqueous phase. Therefore, these two spent acids, together with the hydrocarbon phase from the hydrolysis operations, were burned at boilerhouses. With this acid flow, about 55% of the fortified acid charged to the refinery was recovered as concentrated acid. The rest (except for small losses due to entrainment at the process units themselves) was decomposed to SO_2 and released to the atmosphere at the following places: (1) the hydrolysis kettles, (2) the concentrators, and (3) the boilerhouses. In addition to SO_2, black smoke and fly ash often emerged from the boilerhouse stacks when spent acids were being burned.

Reducing Acid Use

One approach taken for reducing SO_2 contamination was to eliminate or reduce the use of acid whenever possible. Through the use of hydrofining, acid treating of gasoline, heating oil, and lube distillates was eliminated. A clay-treating plant was installed to replace acid treatment of aromatic solvents. Hydrofining of solvents is currently being considered. If this is adopted, lube residuum will be the only product which is acid treated. However, in lube residuum deasphalting, the use of a higher solvent-to-oil ratio and tower (rather than drum) deasphalters has allowed acid treating to be reduced by about 80%. Also, white acid is used now rather than black acid, and laboratory experiments indicate that it is possible to hydrolyze the sludge to produce a low-carbon content weak-acid phase which may be used to adjust pH in water effluent treating operations and a relatively pure hydrocarbon phase which may be included in salable products.

Figure 2 shows that only three spent acids are currently produced. However, if hydrofining replaces acid treating of solvents, only spent alkylation acid and spent acid from lube residuum treating will remain.

Acid Regeneration

Although the steps just discussed substantially reduced the amount of sulfuric acid which ultimately is released to the atmosphere as SO_2, it was obvious that in order to eliminate SO_2 contamination completely from this source, the hydrolysis-concentration method of acid recovery must be replaced by a different process—one which has essentially no SO_2 losses. The process fitting this requirement is acid regeneration. In this process, the H_2SO_4 in a spent acid is completely decomposed to SO_2 and then reconverted to H_2SO_4 in a contact acid plant. Depending upon the type of decomposer installed, carbonaceous material in the spent acid is either burned completely to carbon dioxide and water or converted to solid coke.

In 1951 Humble started investigating the possibilities of an acid regeneration plant at Baytown. The company preferred a chemical concern which had experience in the field of acid regeneration to install and operate the plant rather than enter this field itself. In September, 1953, Humble and Consolidated Chemical Industries signed a contract under which Consolidated was to build an acid-regeneration plant adjacent to Humble's refinery and to regenerate Humble's spent acids on a fee basis. The plant began operation in May, 1955.

Generally, but not always, acid regeneration is more costly than hydrolyzing, concentrating, and fortifying. The cost of operating a large acid regeneration plant naturally is greater than operating a smaller sulfur-burning acid plant to fortify concentrated

acid. However, offsetting this difference in costs are credits for shutting down hydrolysis and concentrating equipment. One other credit exists because less make-up sulfur is required in the case of acid regeneration. In some instances, an acid regeneration plant actually might be profitable to the refiner; in other cases, it might be the least expensive method of eliminating the SO_2 contamination problem. In Humble's case, acid regeneration incurs a debit of approximately $1,000 a day when compared with the acid-recovery system formerly used. The investment cost of an acid regeneration plant is of the order of $10,000 a ton a day of acid-producing capacity. This amount is for a plant having a capacity in the range of 300-500 tons/day when charging a spent acid of 80% acidity.

Sour Gases

Another source of SO_2 contamination results from the combustion of hydrogen sulfide contained in sour gases. A look at Figure 3, which shows the flow of sour gases within the refinery, clarifies this. The crude charged to distillation units contains hydrogen sulfide (H_2S) and other sulfur compounds. The H_2S in the crude leaves the crude distillation units with light hydrocarbons. Residuum from the crude distillation is thermally cracked where light hydrocarbons are formed and some of the sulfur compounds are decomposed to H_2S. A heavy gas oil fraction from the crude distillation units is cracked catalytically. In this operation more light hydrocarbons and H_2S are formed. The sour catalytic light hydrocarbons are processed to produce an ethane and lighter stream, a propane stream, and other heavier streams. Since H_2S has a volatility intermediate between ethane and propane, a portion of it leaves with the ethane and lighter stream and the rest leaves with the propane stream. H_2S is removed from this sour propane stream by Girbotol scrubbing. Until January, 1954, H_2S in the streams from the crude distillation units, thermal cracking units, catalytic light hydrocarbon units, and the Girbotol unit went to the refinery fuel gas and was burned in furnaces throughout the refinery.

Early in 1953 a contract was signed with Consolidated under which it would install and operate a sulfur recovery plant at Baytown. The plant, which was completed in January, 1954, charges concentrated H_2S from the Girbotol unit and produces elemental sulfur. This step removed about 60% of the H_2S from the fuel gas system.

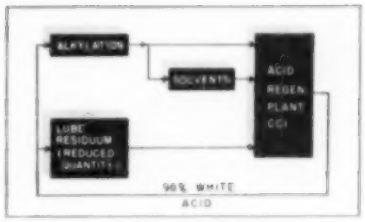


Fig. 2. Current acid flow.

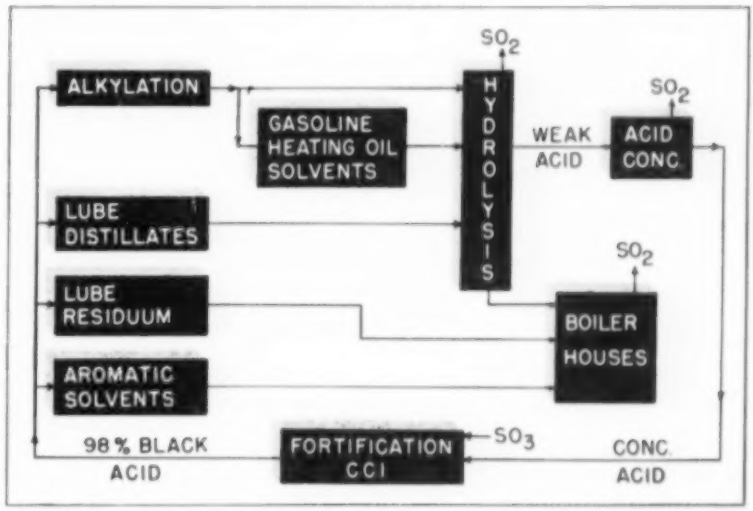


Fig. 1. Acid flow—1951.

Plans in the Making for New Units

Construction will begin soon on a new amine-scrubbing unit which will remove hydrogen sulfide from all remaining sour gas streams with the exception of small amounts in hydrofiner tail gases. Also, two new hydrodesulfurization units are planned. These units will each include an amine scrubber to remove hydrogen sulfide from tail gases, since a policy has been adopted wherein a project which includes a plant which produces a potential air contaminant must include also facilities to prevent the contaminant from being released to the atmosphere in quantities which might be objectionable.

With regard to the economics of sulfur recovery plants, such plants usually show a sizable profit to the refiner in cases where the refinery already has a Girbotol unit in operation. If new Girbotol facilities are required, sulfur recovery may or may not be profitable, depending mainly on the quantity involved. The investment cost of a sulfur-recovery plant is of the order of $8,000 a long ton a day

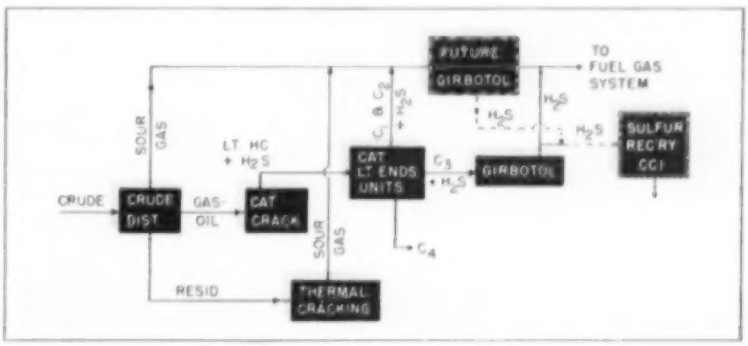


Fig. 3. Hydrogen sulfide flow.

capacity for a plant in the 50-100 long ton a day size range with a sour gas charge containing about 80% hydrogen sulfide and less than 4% hydrocarbons.

One additional source of SO_2 contamination is catalytic-cracking unit regenerator flue gases. A small fraction of the sulfur compounds present in the feed to cat units is adsorbed on the spent catalyst leaving the reactor and subsequently is burned in the regenerator to form SO_2. However, analyses of regenerator flue gases have shown that the quantity of SO_2 released to the atmosphere in this manner is small.

In Table 1 the progress of Humble in reducing SO_2 contamination is summarized. The percentages shown are reductions based on the SO_2 contamination before the reduction program was initiated.

Hydrogenation of gasoline, heating oil, and lube distillates reduced contamination by 3%. Clay treating of aromatic solvents resulted in a 15% reduction. Improved deasphalting of lube residuums through the use of higher solvent-to-oil ratios and more efficient deasphalting equipment permitted an additional 12% decrease. Thus, the total reduction achieved by eliminating or decreasing acid treating was 30%. Installation of the acid regeneration plant reduced contamination by 17% and installation of the sulfur recovery plant resulted in an additional 31% reduction. The total reduction accomplished thus far is 78%. Completion of the Girbotol unit for scrubbing sour refinery gases will result in a SO_2 reduction of 20%, and thus, the total reduction expected by 1958 is 98%. The other 2% occurs through the burning of a small amount of H_2S in the tail gases from the gasoline, heating oil, and lube distillate hydrogenation units.

Table 1.—Reduction in SO_2 Contamination

Step no.	Method of reduction	% reduction
1.	Reduced acid usage:	
	Hydrofining	3
	Clay treating	15
	Improved deasphalting	12
	Sub total	30
2.	Acid regeneration plant	17
3.	Sulfur recovery plant	31
	Total to date	78
4.	Girbotol scrubbing of sour gases	20
	Total reduction by 1958	98

Two benefits which often will be achieved by a contamination reduction program, in addition to improving atmospheric conditions surrounding an industrial plant, are: (1) improved morale in cases where personnel must work in areas within the plant where air is contaminated, and (2) new manufacturing techniques or processes may be developed which result in decreased manufacturing cost or improved product quality.

techniques with radioisotopes . . .

Measuring uniformity of mixing

In mixing paint composed of a pigment and a vehicle, it has been suggested that a short-lived radioisotope be added either to the pigment or to the vehicle, preferably the former.

Manganese 54 (half-life 5.8 days; beta energy 0.6 mev; gamma energy 0.7-1.5 mev) can be added to one component of the drier.

The paint is mixed in special equipment which has a series of counters attached, for example, to the stirring paddles or other mixing devices. Each of these counters is connected to a cable which leads to a multi-point recorder. An instantaneous measurement is made of the distribution of the radioisotopes throughout the volume of the mixing apparatus. When the output from each of these counters is the same, or within limits regarded as equal, homogeneity of the batch is indicated and mixing can be stopped.

Advantages of this system would be manpower savings and the elimination of unnecessary mixing time.

The isotope chosen should have a half-life sufficiently short that the activity will decay to an insignificant value before the product reaches the customer.

Determining liquid level

The radioisotope liquid level gauge is particularly applicable where the liquid in question is extremely corrosive or at exceptionally high temperatures (molten steel, for example).

In principle, the radioisotope is placed on one side of the vessel and the detector in the same vertical plane but diametrically opposite the source. If the liquid level is below this plane, the gamma radiation from the source is only slightly absorbed by the walls of the vessel and the air or vapor space within the vessel. When the liquid level rises above that plane, a large fraction of the radiation is absorbed by the liquid and the intensity of radiation which reaches the detector is considerably reduced.

In a recent application, the method was used to determine the liquid level of strong chromic acid inside a glass-lined evaporator 10 feet in diameter. The source of radiation was approximately 20 millicuries of cobalt 60 (half-life 5.3 years; beta energy 0.3 mev; gamma energy 1.1 and 1.3 mev). Under operating conditions, it was found possible to determine the level of the chromic acid to within ¼ inch.

Measuring wear of firebrick linings

A radioisotope method for measuring the wear of a firebrick lining involves placing a pellet of radioactive cobalt 60 (half-life 5.3 years; beta energy 0.3 mev; gamma energy 1.1 and 1.3 mev) behind selected firebricks at the time the lining is installed.

Radiation transmitted through the layers of firebrick is least when the lining is new and increases as a result of wear. From the known absorption characteristics of the firebrick and the intensity of radiation transmitted, a quantitative measurement of the wear can be made.

An alternative method for determining firebrick wear involves periodically monitoring the melt of iron or glass for radioactivity. When the brick has been worn enough to expose the radioactive pellet of cobalt 60, the pellet will dissolve in the melt and the material from the furnace will become slightly radioactive. By examining the outside of the furnace with a counter sensitive to gamma radiation, it is possible to determine which of the cobalt pellets is missing, thus determining the location of the worn brick.

Condensed from material made available by AEC on Industrial Uses of Radioisotopes.

HOW TO OBTAIN

greater throughput

IN SCRUBBING OPERATIONS

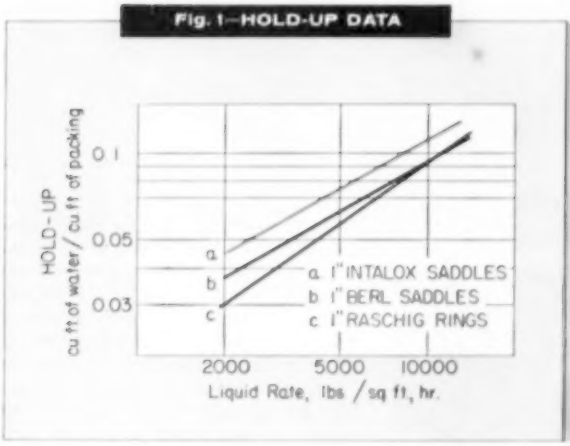
Greatest throughput in scrubbing operations is obtained at a balance point where maximum wetting of the packing occurs without flooding the tower. Maximum wetting involves a higher liquid hold-up.

Intalox saddles pack with greater randomness, form a loosely packed, yet tightly interlocked bed free from blocked areas, with higher surface area, and what is especially important, as far as throughput is concerned, provide a bed of greater and more uniform voidage.

As a result it is possible with Intalox saddles to have a higher liquid hold-up than with other packings yet still retain the low pressure drop characteristics of Intalox since the higher liquid hold-up results from a greater wetted-surface-area rather than from liquid-filled voids.

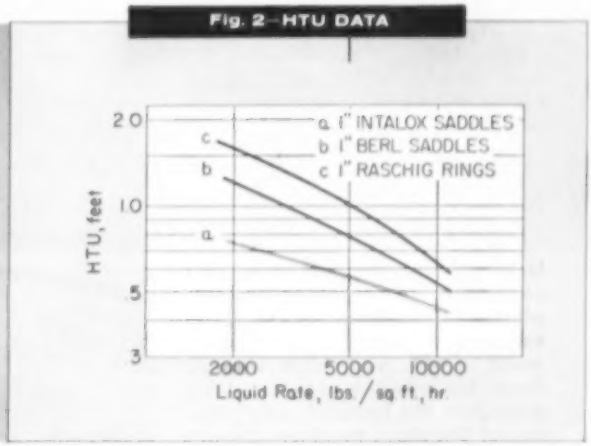
This ability to give higher liquid rates without flooding is reflected in substantially better mass transfer performance.

Fig. 1—HOLD-UP DATA



Higher liquid hold-up of Intalox Saddles reflects the better accessibility of the packing surface to liquid, thus greater wetted surface area. Voids remain open, pressure drop low.

Fig. 2—HTU DATA



The capacity data shown are typical for a system where both gas and liquid film resistances are involved. Lower HTU values mean shorter towers, less pressure drop and reduced initial investments.

Write for this free booklet:

Bulletin S29-R gives full technical data on Intalox Saddles, performance charts, typical problems and solutions. Address: Dept. CEP-357 U. S. Stoneware, Akron 9, Ohio.

U. S. STONEWARE

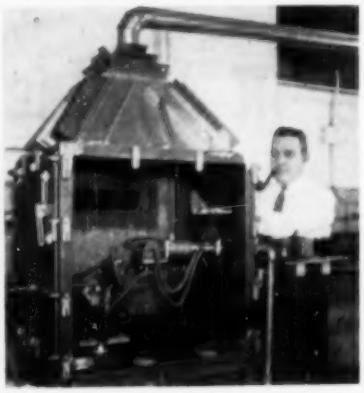
AKRON 9, OHIO

481-E

NEW PROCESS FOR DOMESTIC MANGANESE USES ORE-ELECTRODES

Vitro Corp. is in pilot plant stage with a new process to produce metallurgical manganese from domestic ore, and free the country from dependence on importation of higher grade ores. Unique feature of process is use of a high intensity arc (7,000° to 10,000° C.) with anodes made of rhodonite, a highly refractory domestic manganese silicate so far unusable as a commercial source of the strategic metal.

In search of a method to free the nation from dependence on foreign manganese, Government Services Administration has contracted with Vitro Corp. for Vitro to equip and operate a pilot plant at West Orange, N. J. to develop the "economic factors of full scale production" of manganese from rhodonite by use of a new Vitro process. The result of nearly twenty years' research into chemical processing applications of the high intensity arc, the new process may be only the first application, according to Vitro.



Process co-developer Charles Sheer inspects pilot-plant arc and chamber at West Orange.

Rhodonite, found in large quantities on the Colorado Plateau (an estimated 500 million tons owned by Great Divide Mining and Milling Corp.) is a complex silicate that has defied economical chemical treatment by any known method. Now Vitro is confident it has found the solution to the engineering problem, envisions possible solution of the strategic supply problem as well. (The U. S. uses some 2 million tons of manganese yearly, imports 95% of it from India, Africa and Brazil. More than 60% of the world's supply of manganese is behind the iron curtain, 40% is produced by Russia alone. India is uncomfortably close to the Soviet in case of emergency.) Domestic ores are all refractory and/or low grade, and rhodonite is the domestic ore with the highest manganese content—up to 35% manganese. Vitro predicts that manganese produced by its process will "compare favorably on the economic scale with imported manganese."

The Process—Theory

Developed by Charles Sheer, head of Vitro's arc research department, and Samuel Korman, and called the Sheer-Korman process, the process is electrothermal and similar to those used in the production of calcium carbide, phosphorus, cyanamide, etc., except that instead of being a low intensity arc (seldom over 3,600° C.) it is the first application of high intensity arcs to chemical processing, reaches temperatures between 7,000° C. and 10,000° C. The arc, Vitro says, is

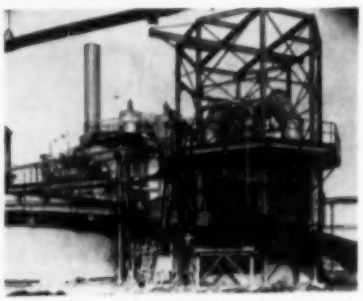
(*Continued on page 52*)

NEW PLANT AND EXPANSIONS HIGHLIGHT NATIONAL DISTILLERS NAME CHANGE

New phosphoric plant, increased capacity in soon-to-be-completed zirconium plant, the company's work with "isosebacic acid" and high energy fuels including hydrazine (and probably the borons), mark National Distillers Products Corp.'s prospective name change to National Distillers and Chemical Corp.

With its U. S. Industrial Chemicals Co. division and its 60%-owned National Petro-Chemicals Corp. accounting for sales in excess of $100 million and totalling 34% of the company's profits at operating level last year, National Distillers Products Corp. is recommending to its stockholders a change of company name to conform with its now large and still growing place in the chemical industry. New name: National Distillers and Chemical Corp.

When the name change goes through, the company will operate with two divisions: National Distillers Products Co. and U. S. Industrial Chemicals Co.



U.S.I.'s new phosphoric plant at Tuscola, Ill.

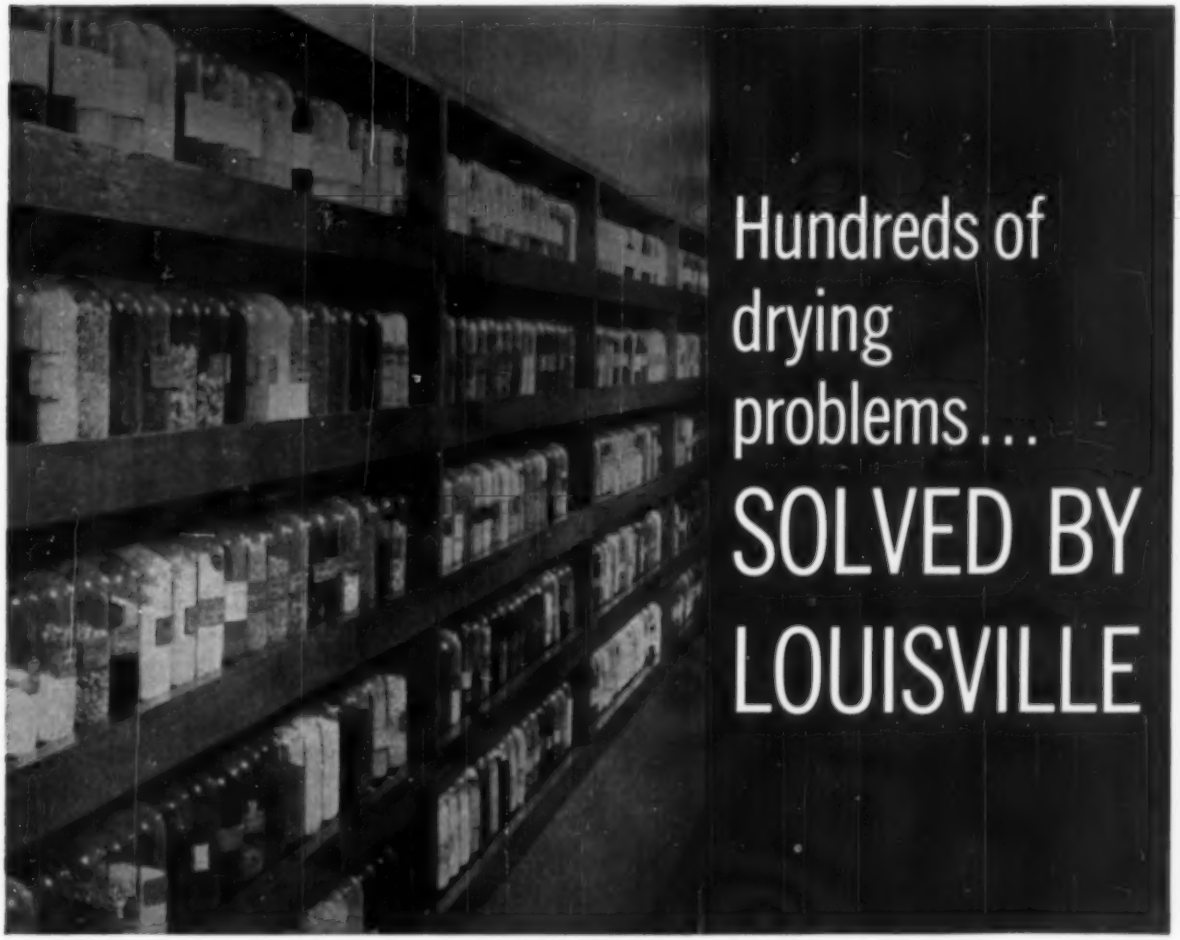
New Plants, New Products

The U.S.I. Division's new phosphoric acid plant has just gone into production at Tuscola, Ill. Annual capacity is 30,000 tons of phosphorus pentoxide, equivalent to about 60,000 tons of 75% phosphoric acid. Sodium silicofluoride for water fluoridation and industrial uses will be a by-product. The new installation, said to be the first in the country to be built primarily to supply the fertilizer field, rounds out U.S.I.'s Tuscola fertilizer center which now produces ammonia, sulfuric acid, and phosphoric acid.

At the soon-to-be-on-stream zirconium plant of U.S.I., anticipated growing industrial need for the metal has prompted the company to increase planned capacity from 1,500,000 pounds a year to 2 million pounds a year. Another new development is that the zirconium will be supplied in "platelets"—small, irregular, flake-like pieces said to be superior to sponge in purity and in ease of handling. At the same time, the company has joined with Mallory-Sharon Titanium Corp. to form a new company, Reactive Metals, Inc., which will soon build a plant to produce pure zirconium metal and fabricate certain mill products.

The company's work in the high-energy fuel field is on a more-or-less hush-hush basis, particularly the rumored work in the boron area, which company spokesmen would make no statement on beyond, "some people have guessed it might be in the field of the borons."

With wide use expected for its "isosebacic acid," particularly as a plasticizer, and a titanium plant going up in addition to the zirconium plant, the company is going deeper and deeper into chemicals, hence its projected name change.



chemicals — pharmaceuticals
brewery by-products — cork products
plastics — corn and soybean products
distillery by-products — foods and feeds
fishing industry by-products — meat packing by-products
fertilizers

Only Louisville Dryers dry so many things so well. Sounds boastful, but only Louisville has the diversified experience... the facilities and the personnel to design and build dryers that are right for so many jobs.

If the manufacture of your product involves a drying process, it will pay you to call in a Louisville engineer. He can show you how a Louisville Dryer, *"tailored" to your need*, can speed up production, improve your product and save you money. Call or write today—there's no cost or obligation.

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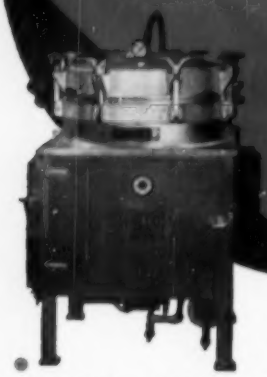

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DOMESTIC MANGANESE

(*Continued from page 50*)

not the process itself, but it is the focal point, and is the means by which the door is opened for processing highly refractory material.

Most important feature of the arc is that the major portion of input electrical energy is concentrated at the surface of the anode (where the ore is located). This efficient transfer of energy makes it possible to vaporize rapidly any material composing the anode; decompose all molecules to their constituent atoms; ionize a considerable fraction of the atoms; heat the vapor mixture to extreme temperature; and project the vapor as a high velocity jet into the surrounding atmosphere where chemical reactions become possible.

The Process—Operation

In operation, the rhodonite is prepared by removing base metal sulfides, the silver and gold by flotation from the crushed ore. The milled ore is then combined with carbon and fabricated into a consumable anode to be fed automatically into the chamber of the high intensity arc.

The detailed composition of the anode and its method of manufacture hold the key to the operation of the process. Critical make-up of the anode is about 20% carbon and 80% rhodonite. The optimum is to achieve maximum conductivity with a minimum carbon content. Vitro states it achieves a power rate consumption of 3 kilowatt-hours for each pound of decomposed ore.

The refractory rhodonite decomposes in the tail flame of the arc just beyond the tip of the anode, and vaporizes and breaks down into elemental manganese, silicon and oxygen (also carbon and some other elements in the anode). As the vapor rises, the temperature drops from the 7-10,000° C. at the cone to about 3,000° C. at the other end of the flame and the elements cool and recombine into simple oxides in the form of a fine fume of submicron particles. The fume, cooled and collected in a dust filter and containing simple manganese oxide and SiO_2, is then processed by conventional leaching techniques. Final product can be manganese metal, battery grade manganese dioxide or ferromanganese.

Economic Factors

Inherent characteristics of the arc are important economic factors. Since

(*Continued on page 57*)

Have safer lines with
less maintenance . . .

INSTALL

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SOLID CHEMICAL PORCELAIN ARMORED WITH FIBERGLASS-REINFORCED PLASTIC

The extra margin of safety essential to many process plants where protection of personnel, equipment and product is vital is assured by the bonding of TUFCLAD fiberglass-reinforced plastic to Lapp Chemical Porcelain. Strong fiberglass fabric is impregnated and bonded in multiple layers to the porcelain with an Epoxy resin of high strength and chemical resistance. It cushions accidental blows—acts as an insulator against thermal shock—and because TUFCLAD is so strong and tough, it will hold operating pressures even when porcelain is damaged by accident. Specify Lapp TUFCLAD Chemical Porcelain and enjoy the purity and corrosion resistance of a solid porcelain system with extra security from TUFCLAD armor.

Y-Valves, as shown, and Angle Valves are available in Lapp TUFCLAD Chemical Porcelain in ½", 1", 1½", 2", 3", 4" and 6" sizes. Also safety valves, flush valves, plug cocks, pipe and fittings (to 8" diameter) and special shapes.

WRITE for description and specifications. Lapp Insulator Co., Inc., Process Equipment Division, 430 Wendell St., Le Roy, N. Y.

Lapp
CHEMICAL PORCELAIN

NORTHEAST AND SOUTHEAST TO LEAD PLANT EQUIPMENT PURCHASES IN 1957

Chemical process equipment purchasing activity will be at a high level in 1957, Northeastern and Southeastern states are expected to lead in dollar volume, and there is a growing interest in new designs and improved or more specifically selected materials of construction.

Prediction of high purchasing activity with leading areas of order placement being the Northeast and Southeast, is based on an opinion survey of the members of CESEA * meeting recently in New York city.

Led by T. T. Meehan, Dorr-Oliver, the annual sounding of purchasing activity in the process equipment field predicted overall dollar volume of sales to the chemical industry will increase by 6-8% in 1957 over 1956. The Northeastern and Southeastern states are expected to provide the largest volume of business, with Southwest and Southcentral states not far behind.

On a quarterly basis, Meehan went on to predict that first and third quarter sales should be up considerably over 1956, second quarter about the same as 1956, and the fourth too far in the future to be indicated by presently available information, and therefore susceptible to international political and economic trends.

Increased interest was reported on the part of purchasers in new designs and new and improved construction materials such as alloys, some plastics, and environment-tailored surface finishes.

One factor of interest, presaging the shift and growth of many industries into full-fledged chemical process industries, is the number of industries other than chemical which are turning to the chemical equipment supplier for counsel and special equipment. Some of these industries are: pulp and paper (see *CEP*, February 1957), coal, and mining and metallurgical.

J. T. Costigan, the Sharples Corp., pointed to the high level of purchasing activity in New York city due to the location there of engineering staffs of many process operating companies.

* Chemical Equipment Sales Engineers Association. Fifteen members and two guests participated in a roundtable session of chemical equipment experts.

CAMPUS ATMOSPHERE, MULTIPLE PARTICIPATION TO MARK INDUSTRIAL RESEARCH CENTER

Major center of industrial research, involving at least seven companies, will be located at Sterling Forest near Tuxedo, N. Y. Unique features: near large metropolitan area (only forty miles northwest of New York City), planned campus-like atmosphere, complex of facilities of seven companies all located in one area.

Near quiet, stately Tuxedo Park, N. Y., (long a playground of highest society) will be a "campus" of industrial research and development intended to bring out the best work from the research engineers and scientists involved. Location is Sterling Forest area, only forty miles from harried and bustling New York City. Organized by a far-seeing group which has acquired title to the land, Sterling Forest may represent the first major planned community of industrial research facilities involving many companies. Idea is to make possible cross-fertilization of minds that can come from locating, in a setting of peace and quiet, not only the varied project facilities of one firm, but of several different firms.

What plans entail: present plans of the organizers of the area call for participation by several firms, all major in research and development. Each will work out its own plans, each plan will presumably be coordinated into overall scheme of the community. Additional industrial firms are said to be considering the project. Sterling Forest Corporation is keeping the installations rigidly controlled to guarantee the desired "research climate."

Although a number of firms are involved in the project, only one has announced its plans so far. This is Union Carbide Nuclear, already laying the groundwork for its Nuclear Research Center in the area.

Carbide Center

Major facilities of Carbide Nuclear's new center will include: a five megawatt pool-type reactor, a Radioactive Materials Laboratory, an Ores and Engineering Laboratory, and a building for allied research operations and administrative functions.

Research programs will be geared to the study of the effects of radiation on products and processes involving plastics, gases, metals, carbons, and chemicals. Special investigations involving chemical analysis and ore processing have already started in a temporary laboratory near the site.

The reactor itself, to be built by AMF Atomics, Inc., a subsidiary of American Machine and Foundry Co., (formal request for construction permit is now awaiting AEC approval) will be a modified pool-type based on ORNL's Bulk Shield Testing Facility.

In the Radioactive Materials Laboratory the work planned includes studies of chemical reprocessing of fuel plates from the reactor and chemical analysis of radioactive materials.

The program of the Ores and Minerals Section will attack basic but neglected problems such as chemical methods for beneficiating lean ores,

(Continued on page 58)

TURN FOR MORE NEWS ON
INDUSTRY ..... page 57 et seq.
NUCLEAR ..... page 94
INSTITUTIONAL ..... page 106
RESEARCH ..... page 120

Artist's drawing of the new Union Carbide Nuclear Research Center at Sterling Forest, N. Y. Reactor building is top rear, engineering, right.

Partial List of Material Processed with Allis-Chalmers Heat Transfer Equipment

- Limestone
- Lime
- Dolomite
- Magnesia
- Alumina
- Bauxite
- Manganese Oxide
- Iron Ore
- Phosphates
- Refractories
- Foundry Sand
- Petroleum Sand
- Petroleum Coke
- Fuller's Earth
- Nickel Ores
- Copper

How Allis-Chalmers Can Help You

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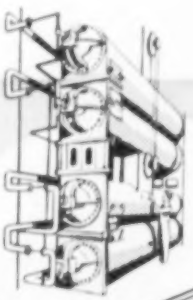
Obtaining increased production, lower processing costs and improved product quality is more than a matter of installing the best heat transfer equipment. Maximum utilization of that equipment also calls for an *efficient flow design*. You get *both* from Allis-Chalmers.

A-C Engineers Work With Your Staff or Consulting Engineers

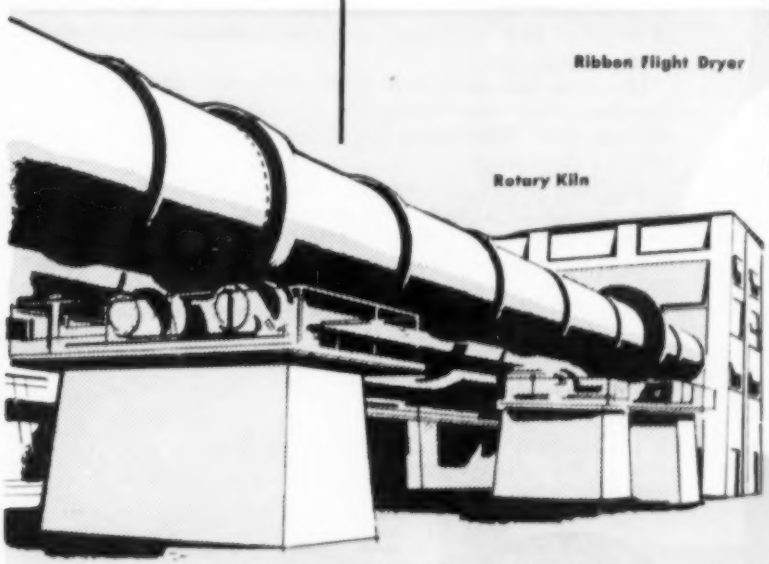
Allis-Chalmers engineers concern themselves with overall operation . . . the evaluation of variables . . . plant design . . . the integration of interdependent equipment into a complete process.

Pre-recommendation research, testing and, of course, expert installation and localized field service are also available from Allis-Chalmers — the world's leading manufacturer of rotary kilns, coolers and associated equipment.

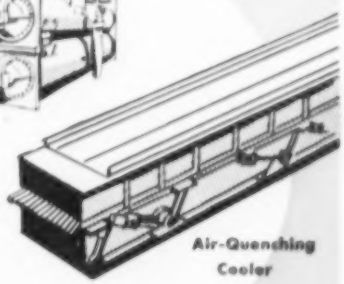
Equally important is the fact that Allis-Chalmers interest in your problems is continuous. Laboratory services, periodic equipment check-up and parts service are yours for the life of the equipment — and a long life it is, too.



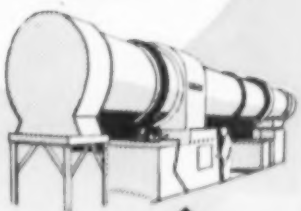
Ribbon Flight Dryer



Rotary Kiln



Air-Quenching Cooler

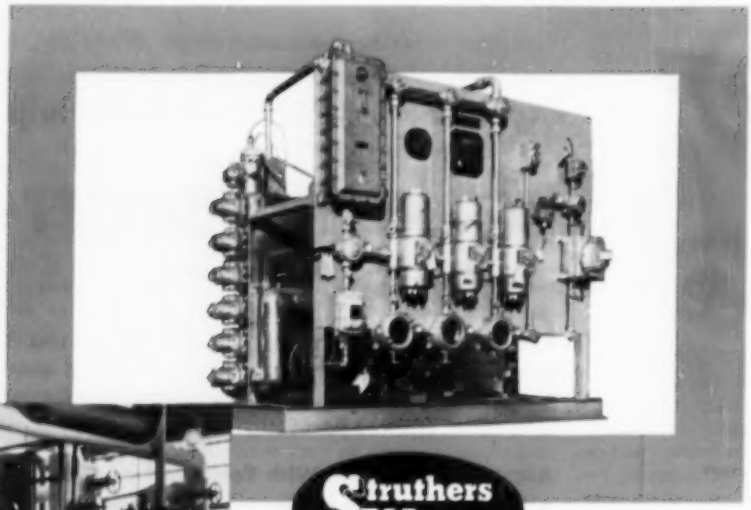


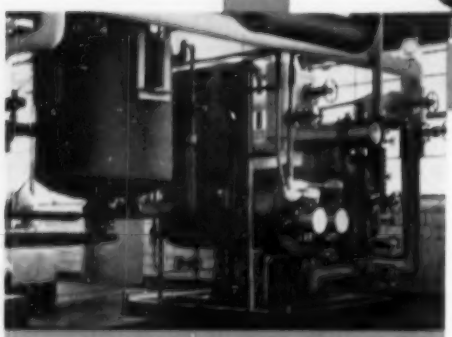
Rotary Dryer

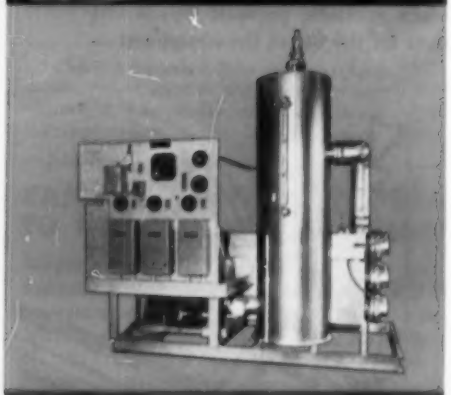
You'll want Bulletin 25C6177. See your nearby A-C representative or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wisconsin.

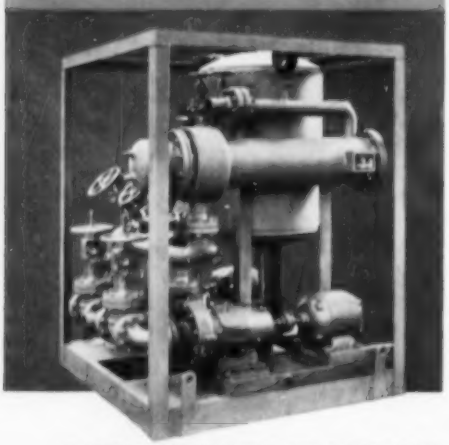
ALLIS-CHALMERS

A-5325









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High Temperature Heating

by Circulating Medium

Struthers Wells supplies circulating heating equipment for a wide range of temperatures and sizes. Many smaller units can be supplied as a "package," completely assembled and ready for operation.

The units illustrated show three electrically heated units for Dowtherm and other fluids, for capacity to above 1,000,000 BTU per hour. Also shown is a circulating cooling unit, (lower left side illustration).

Struthers Wells can supply standard units for capacities from 100,000 BTU per hour to about 40,000,000 BTU per hour. Temperatures range from about 350°F to above 1500°F.

Fired heaters for a wide range of services, including steam superheating, oil and gas heating are also a Struthers Wells specialty. Hundreds of units are in successful service.

If you require heat above the temperature range of available steam pressures, Struthers Wells engineering experience and facilities are always available.

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DOMESTIC MANGANESE

(*Continued from page 52*)

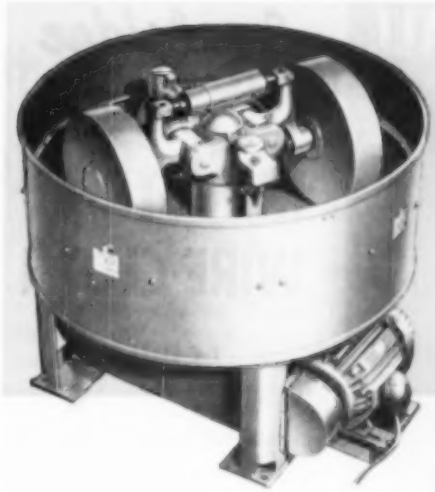
there is no problem of heat build-up (the arc can be started and stopped instantaneously and reaches maximum temperature in seconds). Vitro explains that commercial installations can be small and can take advantage of cheaper "rolling reserve" power (on the order of 3-4 mills per kilowatt-hour). Heavy thermal insulation is not needed since the chamber remains relatively cool.

To keep the size of electrical equipment within bounds, Vitro thinks a commercial plant would probably use a combination of several arc units operating simultaneously, housed in one chamber, product take-offs channeled to a central collection point.

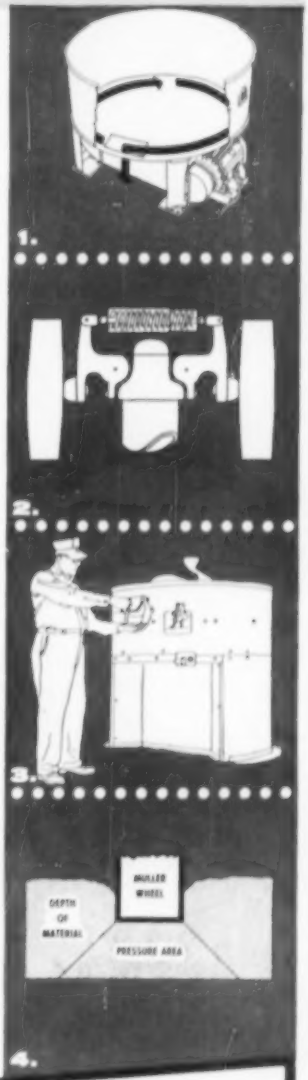
Not the only process to be developed in recent years (much in the news lately has been a ferromanganese process of Strategic-Udy Metallurgical and Chemical Processes, Ltd., developed by Martin J. Udy, *CEP* January 1957), Vitro's process is still in the pilot-plant stage, commercial application will depend on economic factors studied there. But the company is confident of the success of the process, has formed a special subsidiary, U. S. Manganese Corp. (40% owned by Vitro, 40% by Sheer-Korman Associates which holds the patents, and 20% by Great Divide Mining and Milling Corp., which has the rhodonite).

New $20 million electrolytic chlorine-caustic plant will be designed, engineered and constructed for Wyandotte Chemicals Corp. by The Fluor Corp. Site will be near Baton Rouge, La., where an $8 million ethylene oxide plant of Wyandotte is already under construction. Construction will begin in mid-1957, will be completed in last half of 1958. The new plant will increase Wyandotte's chlorine-caustic capacity by some 60%. □

This "floating warehouse," capable of carrying up to 2,900 short tons of cargo in fresh water, has joined the barge fleet of C. G. Willis, Inc. The new barge will be used to carry steel, soap products, paint, lubricating oils and other process industry products. Built by Dravo Corporation, the huge barge is 43 feet wide, 256 feet long and draws 11 feet of water when fully loaded.



Here's why MIX-MULLER® is today's BEST BUY in MIXING EQUIPMENT



The advantage of preparing dry, wetted or plastic materials in a Simpson Mix-Muller is written in *savings*. Controlled mixing *cannot fail* to result in effective utilization of raw materials. Adequate control over moisture, alone, can mean the difference between an unwieldly reject ratio and a profitable mixing operation. See how these four outstanding features of the Simpson Mix-Muller are designed to save you time, labor, material, power, maintenance and *money*:

1. BOTTOM DISCHARGE • STATIONARY PAN. Mix-Muller power is used to mix . . . none is wasted to move machinery or material mass. Muller and plow action clears pan quickly, thoroughly.

2. SPRING LOADED MULLERS . . . allow muller pressure to be adjusted to the type and density of materials to be mixed. You reduce mulling time, build desired properties faster.

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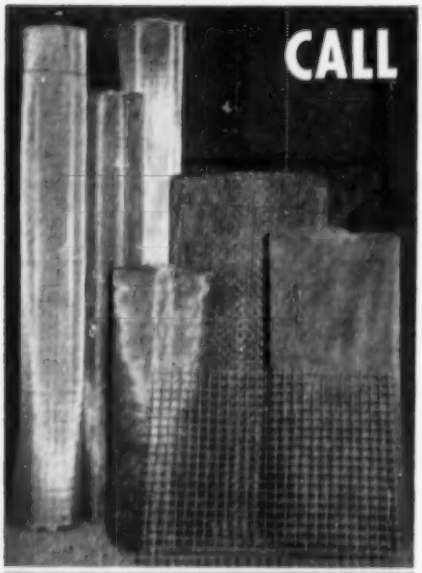


Cambridge

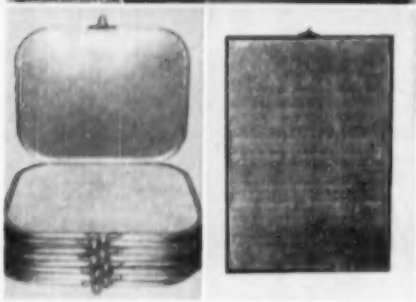
for

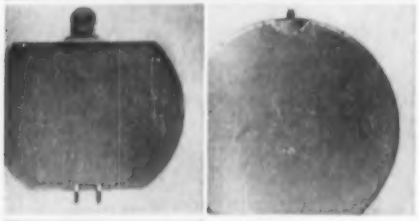
INDUSTRIAL WIRE CLOTH

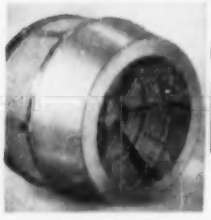
in BULK

or

FABRICATED PARTS







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OFFICES IN PRINCIPAL INDUSTRIAL CITIES

NUCLEAR CENTER

(*Continued from page 54*)

and the search for new approaches to processes for refinement of minerals. In the Chemical Engineering Section the program will have to be guided by results in the reactor and hot lab sections, but, judging from projects already initiated, it can be expected that work will begin immediately on such projects as experimental phases of reactor fuel processing, and developmental preparation of metal-organic chemicals.

In the Main Research Laboratory itself, much work will undoubtedly be devoted to investigation of radiation damage, impurities in ores after mild radiation, study of materials altered by neutron bombardment, and the improvement of products and processes of Union Carbide.

National Cylinder Gas Co. will build or expand industrial gas production facilities at six locations. In Chicago, the company plans a $3 million addition to its liquid oxygen plant that will increase output by 150%. At San Leandro, Cal., the company is completing construction of an oxygen plant to go on-stream early this year. A new hydrogen compressing plant has just gone into production at Huntsville, Ala. For San Juan, P. R., it is an oxygen and acetylene plant, construction already started. In Venezuela the company's Maracay oxygen plant will be doubled in capacity, and a new oxygen plant will be built at Puerto Ordaz. □

A programmed general-purpose analog computer is now for the first time an integral element of oil refinery process control at the Belot Refinery of Esso Standard S.A. near Havana, Cuba. Eleven basic operating guides will be calculated by the computer and recorded hourly, along with 101 critical process variables. Esso engineers expect that the major contribution of this data-handling system will be up-to-date operating information that permits closer process control by eliminating error due to time lag in manual calculation. The automatic data logger was designed and built by Fischer & Porter to Esso Research and Engineering's specifications.

Inside Story on POWELL CORROSION RESISTANT VALVES

Corrosion resistant valves may appear to be alike on the outside. But inside -- in trim materials, in design, in manufacture -- there can be a world of difference. And the inside story of Powell Corrosion Resistant Valves is that every valve has PERFORMANCE VERIFIED.

The reason there's a big difference in Powell Corrosion Resistant Valves is quality control. It begins not with manufacture -- but with the very materials which go into Powell Valves. As a final step of Powell's rigidly enforced quality control, every Powell Valve is subjected to an actual line test.

Powell has designed many new types of Corrosion Resistant Valves to meet the needs of the rapidly expanding chemical and process industries. The variety of pure metals and special alloys in which they are available has grown to such an extent that today there is a Powell Corrosion Resistant Valve to control the flow of almost every known corrosive fluid.

Consult your Powell Valve distributor. If none is near you, we'll be pleased to tell you about our COMPLETE quality line which has PERFORMANCE VERIFIED.

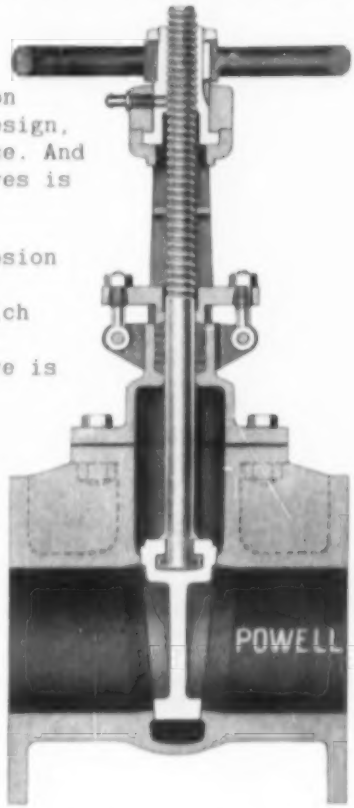


Fig. 2453-SG — Stainless Steel O. S. & Y. Gate Valve for 150 Pounds W. P.

Fig. 1314-A — 1500 Pound Integral Bonnet Alloy Steel "Y" Valve.

Fig. 2342 — Alloy Steel Bolted Cap Swing Check Valve for 150 Pounds W. P.

PERFORMANCE PV VERIFIED

The Wm. Powell Company, Cincinnati 22, Ohio . . . 111th YEAR

POWELL VALVES

BRONZE, IRON, STEEL AND CORROSION RESISTANT VALVES

Peristaltic-action

PUMPS

Pump Liquids Peristaltically Through Rubber or Plastic Tubing

Small Pump *(shown above)*
pumps at a rate of .2 ml. per hour to 15 ml. per minute, adjustable during operation. Device can be used for: administration of sterile fluids to animals; perfusion of body organs; micrometering, etc.
Cat. No. 5-8950, furnished with initial supply of plastic tubing **$159**

Large Pump *(at right)*
pumps at a rate of 25 to 600 ml. per minute, adjustable during operation. Used for transferring or circulating corrosive fluids; transfer of pathogens between containers; circulation of fluids in cooling systems, etc.
Cat. No. 5-8952, furnished with initial supply of plastic tubing **$385**

Full information contained in

Bulletin 2288-5

furnished upon request

AMINCO

AMERICAN INSTRUMENT COMPANY, INC.

SILVER SPRING, MD., IN METROPOLITAN WASHINGTON, D.C.

$38 MILLION NEW CHEMICAL FUEL PLANT

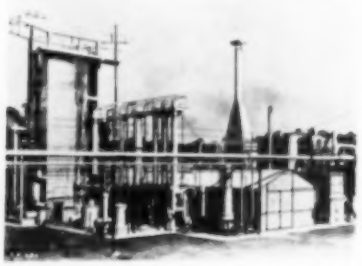
A $38-million plant to produce a completely new type propellant for rocket and aircraft applications is in the works at Callery Chemical Co., a subsidiary of Mine Safety Appliance Co., Pittsburgh, Pa.

The new type chemical fuel, which did not exist a year ago, will deliver more energy per pound than any current fuel. Still under wraps—what it is, or how it is produced—is still classified data. The fuel is important enough to rate the large investment which is being financed by the Navy Bureau of Aeronautics, and the location of the plant will be on Navy land two miles east of Muskogee, Okla.

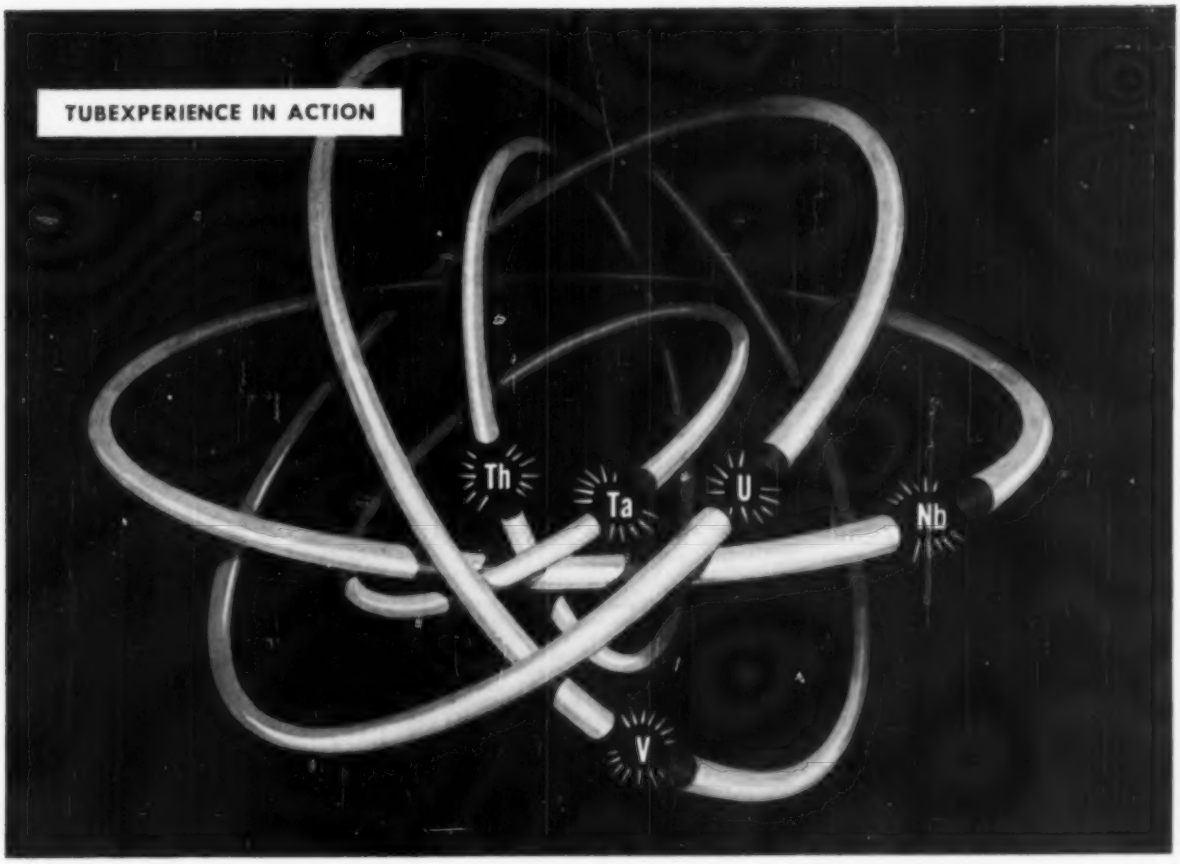
The Muskogee plant will represent the culmination of 8 years' research by Callery on the development of new high-energy chemicals. Since 1952, The Ralph M. Parsons Co., Los Angeles, has been working with Callery on the engineering phase of the program, will now have charge of the complete design and procurement aspects. The construction will be a "grass-roots" job, starting with an open field and building from there.

Spencer Kellogg and Sons, Inc., is now in commercial production and distribution of its own brand of lecithin. □

The Carborundum Company will build a new multi-million-dollar plant in Van Wert, O., for the manufacture of high volume, small abrasive wheels. □



In this demonstration plant acetylene is being produced by a new process developed by Societe Belge de l'Azote (SBA) of Liege, Belgium. Offered in this country by Chemical Plants Division, Blaw-Knox, the new process is said to offer better results in the manufacture of acetylene from natural gas because it eliminates production headaches which have plagued other pyrolysis processes. The SBA burner is a patented design which limits the formation and deposit of soot, and in the acetylene purification step ammonia is used as the solvent rather than the more expensive solvents commonly used.



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- *Superior has supplied millions of feet of tubing for atomic applications to many of the key manufacturers in the atomic field.*
- *Superior has already successfully manufactured tubing from uranium, vanadium, niobium, tantalum and thorium.*
- *Superior has 9 years' experience in drawing tubing from titanium and titanium alloys.*
- *Superior was the first mill to produce tubing from Zirconium, Zircaloy-2, and Zircaloy-3.*

. . . And Superior has produced all this tubing to exceptionally precise specifications and tolerances!

Put Superior's experience and facilities to work for you! Superior has drawn most of the reactive metals, as well as stainless steels, nickel alloys, ingot iron, and Inconel, for important nuclear applications.

The end uses for Superior tubing in atomic energy include control rod tubing, fuel element tubing, tubing for moderator and shielding cans, process lines for handling radioactive liquids, and tubing for handling facilities.

NOTE: In some cases, tubing can be produced only with AEC release, because of priorities on materials.

If you are in or serving the atomic industry and need small tubing, this store of experience can be of great assistance to you. For information, write Superior Tube Company, 2011 Germantown Ave., Norristown, Pa.

SEND FOR LATEST DATA ON ZIRCONIUM—*Write for your free copy of Special Analysis Memo 112—on zirconium, covering properties, fabrication and other data.*

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OXYGEN ANALYZERS!

For time-saving, *accurate* measurements of Oxygen in your process or laboratory operations, select from the complete range of Oxygen Analyzers offered by Arnold O. Beckman, Inc.

Each instrument operates on the field-proven Arnold O. Beckman *paramagnetic* principle which makes a direct physical measurement on the Oxygen itself. No chemicals, no complicated secondary relationships are used!

MODEL C—For higher accuracy with narrower ranges (than available with the D2), the Model C will meet your more advanced needs. Select almost any single range 0-5%, 0-10%, 16-21% 85-100% O_2 etc. (or equivalent in mm O_2 partial pressure). Accuracy is ± 1% of full scale. A 95% response to any reading is obtained in less than one minute. Oxygen content is read directly from a graduated scale. Measurements may be taken on either continuous or fixed volume samples. 115 Volts 50/60 cycles. Weight: 12 lbs.

MODEL D2—Spot-checks on purged tanks, lines, or flue gas are done quickly and conveniently with the Model D2. This unit is completely self-contained, battery-operated and weighs only 3½ lbs. Operation is simple—merely squeeze a bulb to draw sample into the Analyzer, press a switch, and observe the O_2 concentration indicated on the graduated scale. Available with either 0-25% O_2 (0-190 mm) or a 0-100% O_2 (0-760 mm) dual range, the Model D2 accurately performs to ± 2% of full scale.

RECORDING ANALYZERS—For continuous, automatic operation, Models F3 and G2 Analyzers provide millivolt, current, or pneumatic output for operation with standard recorders. Ranges from 0-0.1% O_2 to 0-100% O_2, 16-21%, etc. Multiple ranges, explosion-resistant cases, as well as complete sampling systems are available extras with the Models F3 or G2.

MODEL E2—The precision-designed Model E2 fits the needs of installations requiring maximum accuracy. Offering a choice of single or multiple ranges, the Model E2 provides quick, easy readings when a potentiometer dial is manually adjusted to restore a light beam to its null position. Oxygen content is read directly from the dial. Minimum range 0-1% O_2 with accuracy of ± 1% of full scale. Ranges 0-5% O_2 and wider . . . accuracy ± 0.5% of full scale. 115 volts 50/60 cycles. Weight: 31 lbs.

FOR MORE INFORMATION—Outline your particular problems and let Arnold O. Beckman's experienced engineers offer recommendations for your specialized needs. Bulletins on any and all of the Arnold O. Beckman Analyzers are yours for the asking.

For General Information Ask for Data File 21A-37

Arnold O. Beckman INC.

Profit Buildegs for Industry

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SOUTH PASADENA, CALIFORNIA

INDUSTRIAL NEWS

A $1,500,000 plant to produce reforming catalyst for petroleum refineries has just been completed by Davison Chemical Co. division of W. R. Grace. The reforming catalyst is platinum on alumina and is used in refineries to upgrade the octane level of gasoline. Demand has developed so rapidly that the capacity of the new plant is about double that originally projected.

New plants in the works for DuPont include four major installations. The company's third titanium dioxide plant, with a capacity of 125 tons a day, will be built near New Johnsonville, Tenn. A new 50 million pound a year cellophane plant will be built near Topeka, Kans., is expected to go into operation early in 1959. The nation's first full-scale plant for the production of hyper-pure silicon will be built near Brevard, N. C., is expected to go on-stream early in 1958, will produce about 50,000 pounds of semi-conductor grade silicon annually. At Ecorse, Mich., near Detroit, the company will build a modern sulfuric acid plant expected to go on-stream early in 1958. □

A plant to produce butyl rubber will be built by Petroleum Chemicals, Inc., at Lake Charles, La. Initial plant capacity will be 30,000 tons a year installed at a cost of over $17 million, capacity can easily be expanded by 50% at a later date. □

Booming demand for morpholine has prompted Carbide and Carbon Chemicals to build an expansion of its Charleston, W. Va., facilities that will more than double the plant's capacity. Morpholine, first made commercially in this country by Carbide and Carbon, is produced from diethanolamine, which, in turn, is derived from ethylene oxide. New facilities are expected to be on-stream in 1957. □

A major modernization-improvement program is now underway at Diamond Black Leaf Company's agricultural chemicals plant in Des Moines, Iowa, which will double the capacity of the plant. □

News from
National Carbon Company
A Division of Union Carbide and Carbon Corporation · 30 East 42nd Street, New York 17, N. Y.
Sales Offices: Atlanta, Chicago, Dallas, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco. IN CANADA: Union Carbide Canada Limited, Toronto

PROCESS EQUIPMENT BRIEFS

No Limitations on Economic Design with "Karbate" Heat Exchangers

In addition to superior corrosion resistance, "Karbate" impervious graphite shell and tube heat exchangers offer striking economies in the design and operation of heat exchange systems. "Karbate" exchangers permit economically high tube velocities and consequent reduction in heat transfer surface required – resulting in lower initial equipment costs and operating expense.

A large manufacturer of organic chemicals had used low tube side velocities to prolong the life of carbon steel heat exchangers used in a corrosive monoethanolamine service. This failing, the original units were replaced with "Karbate" shell and tube heat exchangers. After 2 years service, the "Karbate" exchangers showed no effects from exposure to the carbon dioxide-rich monoethanolamine solutions. Even more significantly, the "Karbate" impervious graphite units provide the required heat exchange with less than ⅔ the effective area of the carbon steel units. For full information on "Karbate" heat exchangers request **Catalog Section S-6740.**

New "National" High-Temperature Cement

"National" Cement Grade C-6, a new product developed by National Carbon Company, now makes it possible to fabricate large and relatively complex carbon and graphite structures for high temperature service.

The cement is easily prepared for use by mixing the powder and liquid ingredients shipped in a unit package. Pot life is exceptionally long. After the carbon or graphite parts are cemented together, the cement is cured for a brief period at low temperature. The fabricated structure may then be operated at temperatures as high as 3600°F. with assurance that the cement bond will remain as strong and chemically resistant as the carbon or graphite parts of the structure.

"KARBATE" Impervious Graphite Entrainment Separators Feature Corrosion Resistance, Simplicity, High Efficiency

"Karbate" Impervious Graphite Entrainment Separators – Type MV, now stocked in low cost standard units, are an efficient, economical means for removing entrained liquids from gas streams. These units operate through a combination of venturi action and impingement. Staggered rows of specially shaped vertical impervious graphite rods are contained within an impervious graphite body. Separated liquid collects at the bottom of the rods and is removed through an impervious graphite drain connection.

Type MV Entrainment Separators contain no moving parts and are non-clogging. Streamlined rod shape retards re-entrainment and offers minimum resistance to gas flow. Because corrosive liquid and gas contact only "Karbate" Impervious Graphite, units are virtually immune to corrosion over a temperature range from −40°F. to 338°F.

Standard sizes of "Karbate" Entrainment Separators – Type MV assemble directly into 6", 8", 12", 16", 20" and 24" horizontal lines. Units are self-contained and ready to install. For complete information, request **Catalog Section S-6900.**

"Karbate" Entrainment Separator Type MV ready for installation. Self-contained and shipped ready for use, unit mounts with axis horizontal between standard flanges. Unique design provides effective separation over a wide range of gas flow rates, entrainment content and liquid droplet particle size.

"KARBATE" pumps available in wide capacity range

Standard "Karbate" impervious graphite pumps listed below are carried in stock for prompt shipment. These pumps are used for transfer and circulating service involving corrosives, and deliver 5 to 1500 gallons/minute at heads up to 120 feet and operating pressures up to 100 lbs./square inch. For full information, request **Catalog Section S-7250.**

Pump size			Motor-Mounted	Frame-Mounted
Suction		Discharge	Type F	Type C
2	x	1½	29-FAL	1½-CB
3	x	2	19-FAL	2-CA 2-CB
4	x	3	—	3-CA 3-CB
6	x	4	—	4-CA

NATIONAL TRADE MARK

The terms "Karbate" and "National", "N" and Shield Device are trade-marks of Union Carbide and Carbon Corporation

that by them-
mortgages in the second-
ary, or resales, market.

Coastal Chemical Awards Contract to Fluor Corp.

The Fluor Corporation, Ltd., has been awarded a contract for the engineering and construction of a $2,000,000 phosphate fertilizer plant for Coastal Chemical Corp. at Pascagoula, Miss.

This installation will be Mississippi's first completely integrated phosphate fertilizer plant utilizing basic materials, namely phosphate rock, sulfur, potash and ammonia. It will include a 75 tons-per-day phosphoric acid unit and a 350 tons-per-day granulated ammonium phosphate fertilizer unit. The plant will be the first in the U. S. to utilize the St. Gobain phosphate fertilizer process, developed in France and licensed exclusively in the U. S. to The Fluor Corporation. Engineering is now under way with the job scheduled for completion in January, 1958.

How to solve all of your purchasing problems

Our clients know by experience that when Fluor handles total responsibility for any project; purchasing, expediting and inspection operate as an efficient, time-saving team. Purchasing is a profession at Fluor.

YOU GET THE ADVANTAGE OF BOTH SPEED AND ECONOMY . . . Fluor's unique system of purchasing-expediting assures dependable service. Located strategically in 17 different cities throughout the United States, Fluor's expediters are highly trained men who average more than ten years experience in both inspection and expediting. They can make a personal call anywhere in the U. S. within hours. Net result to you is more efficient purchasing with delivery on schedule—each unit fully guaranteed to completely meet all specifications.

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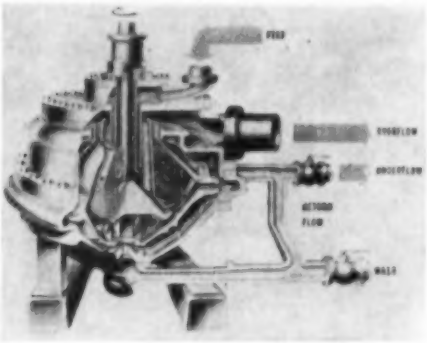
FLUOR *ENGINEERS AND CONSTRUCTORS for the Petroleum, Chemical and Power Industries*

The FLUOR CORPORATION, Ltd., Los Angeles – Mid-Continent Division, Houston – Research Division, Whittier, California – Fluor of Canada, Ltd., Toronto – Singmaster & Breyer, Inc., New York City

CEP Data Service

DEVELOPMENTS OF THE MONTH



388 High Pressure Commercial Centrifuge. Merco Pressure Centrifuge, product of Dorr-Oliver, permits continuous centrifugal separations under pressures as high as 110 lb./sq.in. It will perform the five basic separations of concentration, washing, clarification, soluble recovery and classification.

All solids in the flow are discharged continuously from the unit as the return flow flushes solids at the periphery of the rotor by stepping up nozzle flow two to ten times the underflow actually withdrawn. A hydraulic hoist built into the standard mounting provides easy access for inspecting the unit, nozzle replacement, or change in operations. Uniform product is assured by continuous operation without shutdowns or frequent interruptions for cleaning or repairs.

The unit is available in two sizes, the PC-30 model with capacities from 40 to 250 gal./min., and the laboratory scale PC-9 model with capacities of 1 to 20 gal./min.

Detailed bulletin available from the manufacturer. Circle number 388 on Data Service Post Card on next page for further information.

ENGINEERING DATA—EQUIPMENT

301 Steam Jet Heater. Complete engineering details on all types of SK steam jet heaters. Also data on rotameters, valves, heat transfer equipment, gear pumps. Schutte & Koerting Co.

302 Washable Automatic Weighing Unit. In new Glengarry Model B weighing unit, the entire mechanism is sealed in a cast aluminum enclosure. All contact parts of stainless steel. Glengarry Processes, Inc.

303 Close-Coupled Pump Data. Tables for determining horsepower, capacity, & head for vertical pumps. Also specifications & schematic application drawings of Verti-Line pumps. Layne & Bowler Pump Co.

304 High Pressure Flow Meter. Rated at 15,000 lb./sq. in. Flow ranges from 0.1 ml. to 13 liters per minute. All-stainless steel, non-magnetic construction. Details from C-Mar Corp.

305 Fin Tube Heat Exchanger Data. Curves giving materials, sizes, & performance of the Alcotwin exchanger. Alco Products, Inc.

306 Air Compressor Data Sheet. Construction details, specifications, and models of air compressors in the ¼-20 hp. range. Brunner Manufacturing Co.

307 Stainless Products Catalog. 104-page catalog on stainless steel pipe, valves, fittings, tubing, & specialities. Complete specifications & descriptions. Power Stainless Products Co.

308 Pinch-Type Valve Data. Sizing information, capacity formulas, flow characteristics, installation, & maintenance instructions. Ferris Flexible Valve Corp.

309 Corrosion-Resistant Centrifugal Pumps. 1 to 80 gal./min. at heads up to 75 ft. Specifications and performance curves of Bart "Flex-Seal" centrifugal pumps. Bart Laboratories.

310 Entrainment Separator Design Data. Design, construction, & performance details of "Schuylernit" entrainment separators. Many calculations & charts. Schuyler Manufacturing Corp.

311 Weather-Protected Motor. New Type FOD motors for non-hazardous out-door installations available from Allis-Chalmers Manufacturing Co. In ratings of 250 hp. and larger. Design & engineering details.

312 Mixed-Bed Regenerative Demineralizer. Purification by ion exchange to produce water with resistance of over 1,000,000 ohms/cc. now possible with Bernstead

(Continued on page 70)

DEVELOPMENTS OF THE MONTH (*Cont.*)

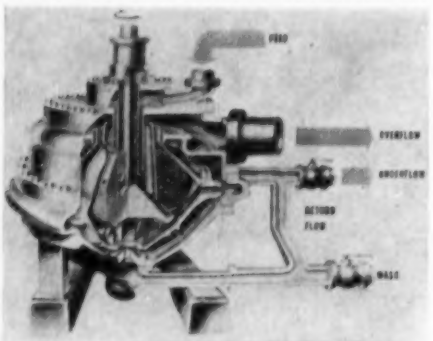
389 Positive Displacement Flowmeter. A high-accuracy meter capable of operating at elevated temperatures and pressures with fluids of high viscosities, either lubricating or non-lubricating.

The meter operates on the principle that the quantity of liquid displaced by each stroke may be integrated by a counting mechanism.

Available in sizes from 1 in. to 6 in. or up to 450 gal./min. capacity, temperatures up to 660° F., and pressures up to 600 lb./sq.in. Guaranteed accuracies are ¼% in 1 in. sizes, and ½% in 2 to 6 in. sizes. Bulletin from Brooks Rotameter Co. Circle number 389 on Data Service Post Card on next page.

CEP Data Service

DEVELOPMENTS OF THE MONTH



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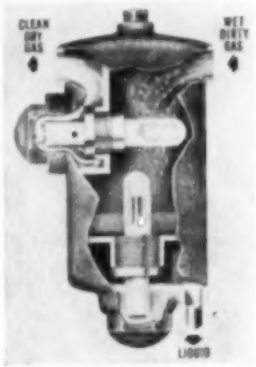
DEVELOPMENTS OF THE MONTH (Cont.)

390 Liquid–Gas Separation Device. The Selas Liqui-Jector completely removes suspended liquid (water, oil, or emulsion) and solid particles from process and instrument gas supply lines.



The Liqui-Jector operates by phase separation—trapping solids, and passing liquid in one direction and gas in another—without interrupting the flow through the line. Maintenance costs are reduced to a minimum, according to the manufacturer, because there are no moving parts and because no extra pipes or special fittings are required.

The units are now available in three standard models: Series A for volumes up to 100 std. cu.ft./min. at 150 lb./sq.in.; Series B for volumes up to 7,000 std. cu.ft./min. at 200 lb./sq.in.; and Series C for conditions where unusually large volumes of condensate are encountered. Specially-engineered units will be built for unusual applications, or where extremely high flow or low pressure drop are required. Details from the Selas Corp. of America. Circle number 390 on Data Service Post Card.

(Continued on page 67)

JUST A MOMENT is needed to learn how to use this insert. When looking through the front part of the magazine, pull the folder portion of the insert out to the right, and the numbers on the post card are convenient for circling.

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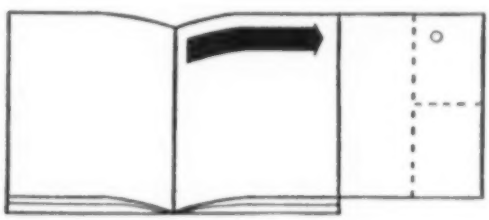

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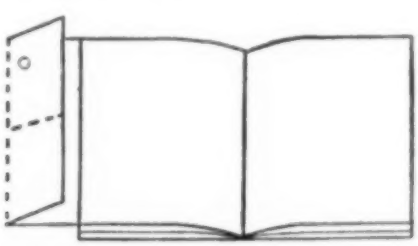

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Be sure to include your name, address, and position.

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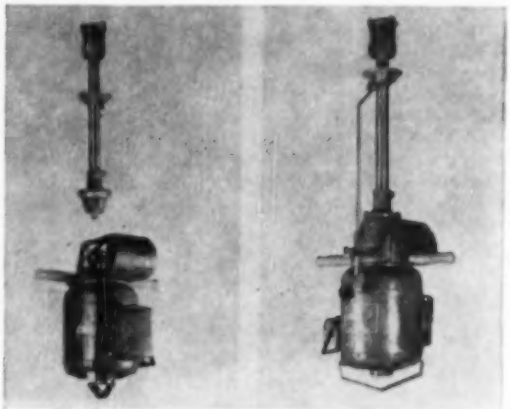
DEVELOPMENTS OF THE MONTH (Cont.)

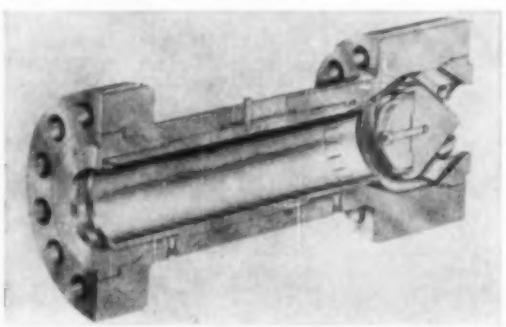


391 Interchangeable-head Mixers. In the Shear-Flow industrial mixer, the complete mixing head is a compact self-contained unit consisting of the mixing shafts, stator-housing, counter-rotating impellers, seals, and all related parts. Removal of four retaining bolts and loosening of the drive belt disengages the mixing head, permitting the insertion of a new head as soon as the other is removed. Spare mixing heads are available for all production models in 3 impeller sizes. All parts subject to immersion are constructed of corrosive-resistant materials. Manufactured by Gabb Special Products, Inc. Circle number 391 on Data Service Post Card.

A.I.Ch.E. MEMBERSHIP

Brochure—"Know Your Institute"—tells objective aim and benefits to chemical engineers who join this nation-wide organization, includes membership blank. Circle number 392 on Data Post Card.

393 Fluidal Balanced-piston Valves. Fluidal valves, by virtue of new design, are compact, fast acting, remote-operated control valves which have low pressure drop. The balanced piston design makes operation of the valves independent of line pressure, the only force required being that necessary to overcome O-ring friction and inertia. This relatively small force can be obtained by fluid pressure against a small annular area on the O.D. of the sleeve-like piston and, since the stroke is short, the volume of actuating fluid required is small. This small volume requirement makes possible a control response on the order of one hundred cycles per second. The same design which makes possible high speed response also makes operation possible at very high pressures. The valves are available in sizes from 1½ in. to 16 in. in the 900 lb. series, at line pressures up to 1,500 lb./sq.in. at 250° F. Custom-built valves can be furnished to 8,000 lb./sq.in. Temperatures are limited only by the composition of the O-ring seals. Bulletin from Fluidal Valves, Inc. Circle number 393 on Data Service Post Card.



(Continued on page 70)

PRODUCTS ADVERTISED IN THIS ISSUE

IFC Technical Literature. Seventeen recently-revised booklets available from Carbide and Carbon Chemicals Co.

3R Rotary Sifter Bulletin. Describes Model "M" Bar-Nun Rotary Sifter. 2 to 76 square feet of screen surface. B. F. Gump Co.

4A Demisters. Yorkmesh Demisters eliminate entrainment in concentrators, evaporators, vacuum pans. Bulletin from Otto H. York Co.

6A Fire Pumps. F-M pumps are specially adapted for fire-prevention systems. Technical details, consulting services from Fairbanks-Morse.

7A Small Flow Control Valves. New Model 9460 designed for working pressures to 6,000 lb./sq.in. Bulletin with complete specifications from the Annin Co.

9A Heat Transfer Medium. Dowtherm provides temperatures to 750°F. at pressures below 150 lb./sq.in. Dow Chemical Co.

10A Heat Exchangers. Custom-built or standard equipment to meet any specific processing needs. Adsco Industries.

11A Hydrogen Plants. The Girdler Co. is highly experienced in design and construction of facilities for high or low-purity hydrogen.

12A-13A Plant Processing Equipment. Bulletin covering Allis-Chalmers equipment for the process industries.

14A Plant Design and Construction. Catalytic Construction Co. are experienced in design of wide variety of process plants for the petroleum and chemical industries.

15R High Pressure Needle Valves. In large or small sizes for refineries or chemical plants. Illustrated bulletin. August Spindler & Sons.

16L Metallic Filter Cloth Catalog. Available in a variety of weaves and in all malleable metals. Newark Wire Cloth Co.

17A Valve Bodies. Super "70" Series valve bodies available in single port, double port, and split-body styles. Black, Sivalls & Bryson, Inc.

18A Steam Jet Vacuum Pumps. Simple design, low initial cost, long life. Bulletin from Schutte and Koerting Co.

23A Gas Pumps and Blowers. Roots-Connersville Blower offer experienced consulting services on handling and control of air or gas.

24A-25A Engineering and Materials Catalogs. Product facts from over 500 manufacturers and chemical and raw material data from over 130 suppliers. Reinhold Publishing Corp.

26A Pulverizing Equipment. Mikro-D. pulverizing units are available in all capacities up to more than ten tons per hour. Technical data from Metals Disintegrating Co.

27A Creative Engineering. Badger Manufacturing Co. is erecting the first plant ever designed for the recovery of ethyl benzene by distillation.

28L Heat Exchanger Design Booklet. Heat exchangers built to your specifications in all clads and alloys. Downingtown Iron Works.

29A Magnetic Flow Meter. The Foxboro magnetic flow meter adds no pressure drop, measures fluid velocity directly. Foxboro Co. Technical data.

30A Non Lubricated Compressors. The design of Ingersoll-Rand ES-NL compressors provides compression without oil lubrication, assuring supply of oil-free air or gas. In sizes from 5 to 150 hp.

31A "Packaged" Mixers. Maximum adaptability to all fluid agitation applications. Philadelphia Gear Works, Inc.

32L Cooling Tower Fan Cylinder. New VL (vertically laminated) fan cylinder amplifies fan efficiency and cooling performance. Marley Co.

33A Bulk Material Conveyor Systems. All types of equipment for flexible mechanization of material handling problems. Bulletins from Stephens-Adamson Mfg. Co.

35A Catalyst Data Booklet. Specialty catalysts to aid industrial chemical progress. Davison Chemical Co.

36A-37A Standardized Pumps. Worthington Corp's SESC line offers broad selection of pump modifications. More than 70,480 combinations. Bulletin.

38A Stainless Steels. Consulting services on selection of proper stainless steel for equipment fabrication. Crucible Steel Co. of America.

39A Molecular Sieve Adsorbents. Selective removal of contaminants at temperatures up to 300°F. Booklet from Linde Air Products Co.

41A Employment Opportunities in Engineering. Immediate openings for chemists and engineers in various fields. Chemstrand Corp.

42A Consulting Services on Continuous Drying. Proctor & Schwartz offer specialized knowledge resulting from years of experience.

43A-44A U.S.I. Chemical News. March issue highlights new phosphoric acid plant at Tuscola, Ill. U. S. Industrial Chemicals Co.

45A Mechanically Sealed Process Pumps. Capacities to 1,200 gal./min., case pressures to 600 lb./sq.in. Bulletin from Peerless Pump Division, Food Machinery and Chemical Corp.

46A Heat Transfer Fluid. Aroclor 1248, a highly stable chlorinated phenol, is fire-resistant, operates at atmospheric pressure, noncorrosive. Information from Monsanto Chemical Company.

48A Custom Built Heat Exchangers. In stainless steel, carbon steel, nickel, copper and wide variety of alloys. Vulcan Manufacturing Division.

49A Ceramic Tower Packing. Bulletin gives performance charts, typical problems and solutions, other technical data on Intalox Saddles. U. S. Stoneware.

51A Industrial Dryers. Louisville Drying Machinery Unit, General American Transportation Corp., offer consulting services on any type of drying problem.

52L Oil Reclaimer Systems. Hilco oil reclaimer systems offer lower vacuum pump maintenance costs, increased vacuum. Bulletin from Hilliard Corp.

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56A High Temperature Heating Equipment. Standard units for capacities from 100,000 BTU to about 40,000,000 BTU per hour. Temperatures from 350 to above 1,000°F. Struthers Wells Corp.

57R Mix-Mullers. National Engineering Co. offers bulletin "Mulling for the Chemical & Process Industries."

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62L Oxygen Analyzer Data File. Arnold O. Beckman, Inc. offers complete line of oxygen analyzers to meet specialized needs.

(Continued on page 72)

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(Continued on page 72)

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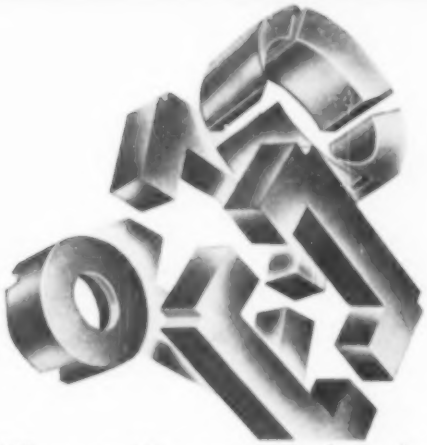
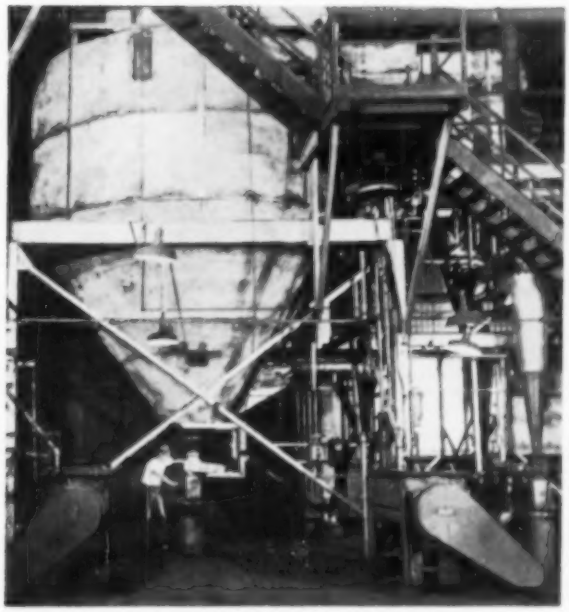
SPRAY DRYER PIONEER

Stackpole Carbon uses Bowen Spray Dryer to produce Metallic Oxide Powders to meet high electrical specifications.

Stackpole Carbon Produces First Spray Dried Ferrites





Bowen Spray Dryer used for the production of metallic oxide ferrites

"Ceramag®" cores made from the spray dried ferrites have lower eddy current losses, less corona effect, high permeability and ability to withstand elevated ambient temperatures, thus they insure superior performance in the electrical and electronic fields where they are used in pulse generation, magnetic amplifying, television and similar applications.

Because of its spherical shape, free-flowing characteristics and high density the spray dried metallic oxide ferrites can be molded into small and intricate shapes. Ceramag® material of Stackpole Carbon has thus been an important factor in meeting the growing demand for miniaturized components.

Bowen Engineering is proud to have had the opportunity to cooperate in this project.

BOWEN TEST LABORATORY— If you have some ideas where spray drying might present a profitable solution, Bowen Engineers will be glad to show you at the Bowen Laboratory what Spray Drying can produce for you. Equipment available will handle small batch lots of a gallon or two, a few drums or a car load for sampling or manufacturing development. Bulletin *"The Bowen Laboratory for the Evaluation of Spray Drying"* more fully describes these research facilities.

GET BULLETIN 41

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NORTH BRANCH 13, NEW JERSEY

Ceramag—Registered trade mark of Stackpole Carbon Company

Recognized Leader in Spray Dryer Engineering Since 1926

BOWEN SPRAY DRYERS
Always Offer You More!

EQUIPMENT (*Cont.*)

MM-O Mixed-Bed Regenerative Demineralizer. Complete details from Barnstead Still & Demineralizer Co.

314 All-Plastic, Self-Priming Pump. Equipped with special Dynel filter medium to remove particles down to one micron in size from acid or alkaline electroplating or industrial solutions. Data from Sethco Mfg. Co.

315 Mixing and Grinding Machinery. Bulletin from Charles Ross & Son Co. describes various types for liquids, semi-paste, heavy paste, & dry materials.

316 Radiation Shielding Windows. Technical bulletin from Corning Glass Works gives compositions, shielding characteristics, transmittance characteristics, & design considerations.

317 Caustic Dehydrating System. Booklet with flow sheet of typical system, detailing individual components & operational features. Swenson Evaporator Co.

318 Differential Pressure Switch. Model 211 indicating switch is suitable for high pressures but is responsive to small pressure differentials. Bulletin from Barton Instrument Corp.

319 Specialty Valves. Bulletin giving engineering data on complete line of Greenwood specialty valves, product of Vernon Tool Co.

320 Humidification Systems Data. Spray nozzles, assemblies and parts for manual or automatic systems. Bulletin from Spraying Systems Co.

321 Data File on Air Control Valves. 71 pages of information including dimensional data, list of parts, price list & flow diagrams. Ross Operating Valve Co.

322 Fan Cooled Motors. Bulletin giving details of motors in ratings from ½ hp. to 40 hp. Frames run 182 through 405. Robbins & Myers, Inc.

323 High Pressure Pump Selection Chart. For pressures to 35,000 lb./sq.in. & capacities to 2,000 gal./hr. Catalog from Philadelphia Pump & Machinery Co.

324 Large Capacity Aero After-Cooler. A self-contained method of cooling & removing water from compressed air, independent of large supply of cooling water. Replaces both shell-and-tube cooler & cooling tower. Engineering data from Niagara Blower Co.

325 Liquid Batching Meter. Repeating Auto-Stop liquid batching meter shuts off automatically when preset quantity is reached. Details from Neptune Meter Co.

326 Air and Vacuum Pumps. 16-page catalog with construction details, dimensions, capacities, new performance curves, installations of rotary positive air and vacuum pumps, gas boosters, and air motors. Leiman Bros., Inc.

327 High-Speed Centrifugals. Bulletins from The Fletcher Works describe wide variety of centrifugals for the chemical processing industry.

328 Thermo-Panel Coil. Replaces pipe coil for industrial heating and cooling processes. Engineering details, dimensions, specifications, & prices from Dean Products, Inc.

329 Horizontal Pressure Filter Data. Operation, control, filter bed materials, design features, available accessories. Also drawings illustrating two, three, and four header units. Cochrane Corp.

330 Package Nitrogen Generator. Oxygen-free nitrogen from ammonia produced in single, portable unit. Capacities from 50 to 10,000 std. cu.ft./hr. Brochure from Baker & Co.

331 Standardized Compressor Pumps. Complete specifications and selection data available from Air-Flo Compressor Co.

332 Forged Steel Needle Valves. For high pressure throttling, gauging, or sampling. Available from stock in ¼-in., ⅜-in., ½-in., and ¾-in. sizes. In 416 stainless steel and other alloys to special order. Bulletin from August Spindler and Sons.

334 Renewable Seat Valves. Bolted bonnet steel valves, in globe, angle, check, "Flocontrol," and high-pressure drop designs available with integral hard-faced or renewable stainless steel seats. Data from Manning, Maxwell & Moore, Inc.

MATERIALS

355 Product Catalog. 1957 listing of products of Union Carbide and Carbon Corp. Now available.

356 Activated Carbon Booklet. Properties of activated carbon and dicussion of its applications in chemical processing. National Carbon Co.

357 Silicone Reference Guide. Catalog describes about 150 commercially available silicone products. Many charts, tables, graphs, comparing silicones with materials they are replacing. Dow Corning Corp.

358 Molybdenum Disulfide Bulletin. Physical, thermodynamic, electrical, magnetic, chemical properties, preparation, and uses. Climax Molybdenum Co.

359 Corrosion Resistant Lining Material. Saraloy 898, product of the Dow Chemical Co., is a flexible thermoplastic with extraordinary resistance to a broad range of acids, alkalis, salt solutions, and solvents. Further information from manufacturer.

360 Tube Fittings Catalog. 28-page catalog covers line of flareless Ferulok Tube Fittings. Includes fittings for mounting in new S.A.E. straight thread boss utilizing O-ring for sealing. Parker Appliance Co.

361 Aluminum Digest. Industrial and production statistics, products and markets, properties, characteristics, and standards. Reynold Metals Co.

362 PVC Pipe Bulletin. Describes line of rigid plastic pipe and tubing. Easton Plastic Products Co.

363 Corrosion Data. 8-page bulletin entitled "Corrosion Resistance of Chromallized Iron and Steel Parts" now available. Many test results and case histories. Chromalloy Corp.

364 Terpene Oxide Data. Structure, properties, reactions, and suggested uses of two

(Continued on page 72)

DEVELOPMENTS OF THE MONTH (*Cont.*)

394 Multistage Dispersion Mill. The "Puc" multistage dispersion mill is designed for maximum efficiency in many chemical processing applications including:

1. Production of colloid suspensions, dispersions, emulsions,
2. Acceleration of chemical reactions on a continuous basis by rapid increase of contact surface,
3. Liquid-liquid extraction processes,
4. Instantaneous and constant rate mixing of interacting chemicals and chemical phases,
5. Particle size reduction of intermediary or end products.

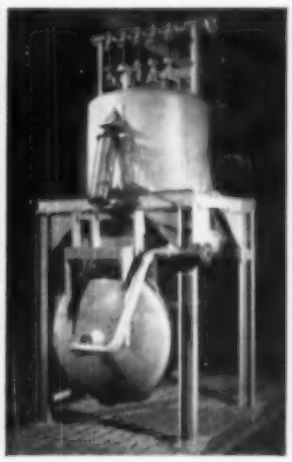
Milling faces consist of conical, ring-shaped, multistage rotor-stator assemblies having from 2 to 5 specific grinding stages. Interchangeable milling assembly combinations to suit a large variety of materials are standard equipment. Steels employed in construction are specially hardened and corrosion-resistant. No water cooling is required.

The Dispersion Machinery Co. will accept samples for testing. Mills of all sizes are available on a small charge basis for a limited rental period. Circle number 394 on Data Service Post Card.

(Continued on page 72)

VEGETABLE OILS
(PF Dry Cake Discharge Filter)

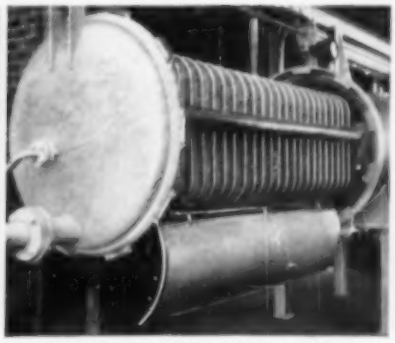
ACID PLATING SOLUTIONS
(PF "Speed Sluice" Filter)



BLEACHING CLAY SEPARATION
(PF Batch Filter)

JET FUEL
(PF Cartridge Filters)

ALKYLATION PROCESS (PF Batch Filter)



FATTY ACID OPERATION (PF Horizontal Filter)

HF GAS PROCESS (PF Carbon Tube Filters)

Have you checked the PF story yet?

It's a revealing record that holds new profit possibilities for you . . . especially if your filtration needs call for more than a "run-of-the-mill" answer.

Process Filters, Inc. specializes in meeting out-of-the-ordinary requirements. Approaching different problems differently, this young, fast-growing concern has come up with dozens of innovations in the past few years to simplify operation, shorten downtime and boost production.

It has developed a line of pressure leaf filters and accessories that can be adapted to an extremely diverse range of process conditions. Exclusive PF Features include Rapid-Opening Covers, Quick-Change Cloth and Paper Bags, Automatic Leaf Shut-Off and Batch Recovery Leaves that provide twice the normal filtering area . . . to name but a few.

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To obtain a realistic, thought-out answer to your filtration requirements, ask to have a PF representative contact you.

For an immediate look at various types of Process Pressure Leaf Filters, write for illustrated Bulletins today.

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PROCESS FILTERS, INC. (A subsidiary of BOWSER, Inc.)

1807 Elmwood Ave., Buffalo 7, N. Y.

MATERIALS (*Cont.*)

new epoxy compounds: dipentene monoxide and alpha-pinene oxide. Becco Chemical Division, Food Machinery and Chemical Corp.

365 Alloy Tubing Test Data. Technical data letters from Babcock & Wilcox Co. give corrosion and high-temperature test data on B&W Croloy 27-4-1 (Type 329) in tubular form and B&W Croloy 25-12 (Type 309S).

366 Butyl Rubber Information Kit. Latest market developments, evaluation of butyl accelerators, and study of carbon black in butyl rubber. Also "types and properties" chart. Thiokol Chemical Corp.

367 Mechanical Packings Bulletin. Description of most popular packings for application in power, industrial and processing plants. Flexrock Co.

368 Adhesive and Coating Formulations. Data sheet entitled "Adhesives and Coatings from Vinyl Ether Polymers and Copolymers" is offered by General Aniline & Film Corp.

369 Tungsten Carbide with Platinum Binder. Typical uses, workability, physical and chemical properties of Kennametal Grade K501 presented in two-page bulletin from Kennametal, Inc.

370 Thin Walled Teflon Tubing. Diameters, wall thicknesses, tolerances, and weights of standard tubing sizes. Bulletin from Haveg Industries, Inc.

371 Isopropylbiphenyl. Now available in pilot plant quantities from Monsanto Chemical Co., this biphenyl derivative is said to offer advantages as a coolant-moderator for nuclear reactors. Technical data sheet.

372 Low Cost Antioxidants. 5-page technical data sheet from Chas. Pfizer & Co. gives physical and chemical properties and applications of isoascorbic acid and sodium isoasco bate.

372 Improved Isocyanate Resin. Complete data on Mondur CB, plus literature on formulating urethane surface coatings and adhesives, offered by Mobay Chemical Co.

373 Non-Ionic Wetting Agent. Triton CF-21, product of Rohm & Haas Co., said to be 100% active and to have unusually low foaming properties. Technical notes available.

374 Felt Filtration Data Sheet. Tables of physical properties and performance characteristics and charts on air or liquid flow rates. American Felt Co.

375 Reagent Price Catalog. Current prices for more than 1,300 reagents and other laboratory chemicals. J. T. Baker Chemical Co.

376 Teflon Hose. Flexonics Corp. announces new line of Teflon hose with stainless steel braided covering. For working pressures to 3,000 lb./sq.in. and temperatures to 500°F. Application data available.

377 Glass Protected Steel. Chemical characteristics and corrosion resistance, physical characteristics and properties. Bulletin from A. O. Smith Corp.

378 Linings and Tile Tanks. Stebbins Engineering and Manufacturing Co. specializes in design, installation and maintenance of corrosion-resistant linings and tile tanks. Consulting services.

379 Plastic Core Valve Stem Packings. Garlock Packing Co. announce two new styles of asbestos braid jacketed plastic core valve stem packings for high pressure and high temperature service. Both use Inconel wire in the packing jacket. Technical data.

380 Plastic Coated Instrument Tubing. "Dekoron" instrument tubing consists of a polyethylene or vinyl sheath extruded over copper, aluminum, or steel tubing. It combines advantages of both metal and plastic. Details from Samuel Moore & Co.

381 Molded Teflon Ball Valve Seats. Sparta Manufacturing Co. offers custom molded Teflon seals in thin sections and shapes. Also flexible thin wall and spaghetti tubing in Teflon. Technical literature.

SERVICES

382 Engineering and Construction Services. Illustrated brochure describes facilities and experience of Kaiser Engineers in all phases of engineering analysis, design, and construction.

383 Nuclear Power Plant Design. General Electric Co. offers booklet describing design of the Commonwealth Edison Dresden nuclear power plant.

384 Chemical Plant Layout Kit. For three-dimensional layout of problems in process and chemical plant design in your own engineering department. Details and prices available from "Visual" Plant Layout, Inc.

385 Industrial Data Systems Information. Beckman Instruments, Inc. offer reprint of article "Increased Reliability of Industrial Data Systems."

386 Plant and Equipment Services. Process development, pilot plant facilities, complete plant design for the chemical and process industries. Bulletin from Crawford & Russell.

387 Liquid-Liquid Extraction Process. 16-page booklet from M. W. Kellogg describes Solvent Decarbonizing, a "paracritical" liquid-liquid extraction process developed to supplement vacuum distillation and recover higher percentage of catalytic feed from residues.

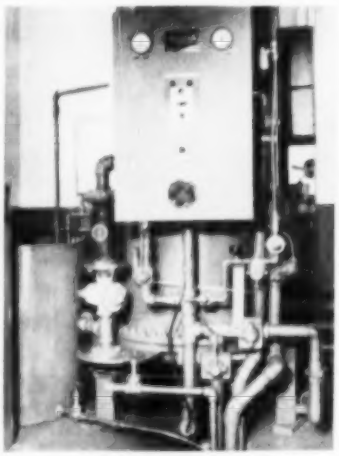
DEVELOPMENTS OF THE MONTH (*Cont.*)

395 Packaged Demineralizer. Of stainless steel construction, the Penfield MA-5000 Demineralizer is an entirely self-contained "packaged" unit, requiring only connection with service lines to start delivering an ultra pure effluent of up to 10 megohms.

Operation is fully automatic. When purity falls below pre-set standards, the need for regeneration is automatically signaled and the turning of a single switch accomplishes a complete regeneration cycle, including rinsing and recutting in effluent when desired resistivity is reached.

Deionization is accomplished on the mixed bed principle—high capacity cation and anion resins in a single column 38 in. in diameter with 90 in. straight sides. Internal collector, screens, valves, and all piping are 100% non-corrosive. Complete technical details available from the Penfield Manufacturing Co. Circle number 395 on Data Service Post Card.

(Continued on page 74)



PRODUCTS ADVERTISED IN THIS ISSUE (Cont.)

63A Impervious Graphite Equipment. Catalogs on "Karbate" heat exchangers, entrainment separators, pumps. National Carbon Co.

64A Engineering and Construction Services. Efficient purchasing staffwork is an important part of Fluor's design and construction services. The Fluor Corp.

69A Spray Dryers. Bowen Engineering, Inc. offer bulletin "The Bowen Laboratory for the Evaluation of Spray Drying."

71A Pressure Leaf Filters. Complete line of pressure leaf filters and accessories adaptable to wide range of process conditions. Bulletins from Process Filters, Inc.

73A Chlorine Vaporizer Systems. Whitlock Vaporizer Systems provide high capacity output at low equipment cost. Details from Whitlock Manufacturing Co.

(Continued on page 74)

Fast, Economical Systems Convert Liquid Chlorine to Dry Vapor

When chlorine in dry gaseous form is required in relatively large quantities, Whitlock Vaporizer Systems provide high capacity output at low equipment cost. The Systems, whose design and construction were suggested by the standards of the Chlorine Institute, Inc., are standardized in design and complete packages in themselves. To operate, it is only necessary to connect steam, condensate, chlorine, and vent lines, and to insulate as required. The five standard sizes handle liquid loads in the range of 500 to 8,000 pounds per hour and provide compact, economical units for efficient operation on any installation. The controls are simple, reliable, and safe. . . . .

AUTOMATIC SYSTEM NOW AVAILABLE

New automatic controls now adapt the standard Chlorine Vaporizer System above to automatic operation. Pressure reducing valves maintain constant pressures in steam and downstream chlorine lines . . . and automatically adjust the input of liquid chlorine to compensate for fluctuations in the downstream load. Controls are wholly automatic and relieve operator of all responsibility for manually adjusting any valves for flow control.

Manually Operated or Automatic, these Systems provide the ready answer to your chlorine vaporizing problems. Write us today for further information and recommendations.

THE WHITLOCK MANUFACTURING CO.
West Hartford 10, Conn.
In Canada: DARLING BROS., LTD., Montreal

* * * \

PRODUCTS ADVERTISED IN THIS ISSUE (*Cont.*)

75A Flow Measuring Equipment. 1700 Series Flowrator meters, product of Fischer & Porter Co., give predictable calibration performance in all ranges. Catalogs.

77A Hydrogen Treating Catalysts. Bulletin from the Girdler Co. gives process conditions, performance features, typical catalyst specifications on G-35 catalysts.

78L Tray Dryers. Completely automatic operation with changeover to manual for test or research runs. C. G. Sargent's Sons Corp.

79A Tubular Filter. Creates own air pressure for fast self-cleaning in seconds. Bulletin from Industrial Filter & Pump Mfg. Co.

82L Storage Tank Equipment Catalog. Conservation vent units, flame arrestors, automatic tank gauges, other tank safety and control equipment. Vapor Recovery Systems Co.

83A Pressure Filters. Eimco Corp. offers research facilities to test your slurry on all types of filtration equipment.

84L "Heliflow" heat exchangers, built by Graham Manufacturing Co., are adaptable to every chemical processing need.

85A U. S. Gasket Co.—Garlock Packing Co. Sales Merger. Sales services of U. S. Gasket Co. and Garlock Packing have been integrated throughout the United States and Canada.

87A Industrial Dryers. Designed to dry air, gases or liquids to sub-zero dew points at low cost. Bulletin from C. M. Kemp Mfg. Co.

88A Continuous Centrifuges. Sharples Corp. offers seven types of continuous centrifuges, each designed for particular jobs.

89R Vapor Conservation Vents. Protectoseal vents are designed for low-cost maintenance, are fully fire protective, simple to maintain. Venting Manual and Safety Bulletin. Protectoseal Co.

91A Plant Design and Construction. Blaw-Knox has had wide experience in both petroleum and chemicals as well as petrochemicals.

92A Vinyl Resins. Complete information and technical service available from Chemical Sales Division, Firestone Plastics Co.

93R Twin Strainers. Twin construction permits one unit to be in service while other is being cleaned. Details from Elliot Co.

94L Fluid Mixing Handbook. 44-page guide to the techniques of mixing. Many tables, charts and nomographs. Eastern Industries, Inc.

95A Polyethylene Tower Packing. "Tellerette," product of Harshaw Chemical Co., is based on the principle of interstitial holdup, assures increased efficiency and capacity.

96L Process Equipment. Packaged liquid coolers, heat exchangers, tank transports, pressure vessels. Bulletins. Doyle & Roth Manufacturing Co.

97A Seamless and Welded Tubular Products. Tubes, fittings and forged steel flanges in carbon, alloy and stainless steels. Babcock & Wilcox Co.

98L Impervious Graphite Cost Data. 32-page report presents costs and equipment specifications on impervious graphite equipment produced by Falls Industries, Inc.

99A Standardized Heat Exchangers. Ross Heat Exchanger offers consulting services in connection with any heat exchange problem.

101A Stainless Steel Fabrication. All types of solid and clad equipment for the chemical processing industries. Sun Shipbuilding & Dry Dock Co.

102L Heat Transfer Equipment. "Paracoil" design creates the proper turbulence to give most efficient heat transfer in exchangers. Bulletin from Davis Engineering Corp.

103A Compressors. Cooper-Bessemer engine-driven and motor-driven compressors assure efficient power at lower cost. Details from manufacturer.

104L Protective Coatings Data. Comparative data chart for estimating protective coating systems. Carboline Co.

105A Pump Data Sheet. Condensed catalog and selection table covering entire line of Aldrich Pump Co. products.

106-MA Relief Valve. Crosby Style JB Protecto Seal Bellows Relief Valve is for services requiring protection against corrosion and fouling of working parts and low back pressure surges. Crosby Valve & Gage Co. Bulletin.

106L Free-Flow Nozzles. Spray Engineering Co. offers 30-page catalog on complete selection of standard nozzles.

107A Soft Vinyl Frame Safety Goggles. More comfort, full ventilation, complete all-around protection. Watchemoket Optical Co.

108TL Chlorine Evaporators. Operate at sustained rates up to 8,000 pounds per 24 hours. Bulletin from Wallace & Tiernan, Inc.

108BL Gravimetric Feeders & Meters. Merchen feeders and meters give automatic control, continuous blending, materials accounting. Wallace & Tiernan, Inc.

109A Plastic Piping. Available in standard wall and pressure-rated pipe, working pressures to 100 lb./sq.in. at 75°F. Booklet from Crane Co.

111A Sealed Pumps. Chempump can't leak because it has no seals, no stuffing box, no packing. Details from Chempump Corp.

112L Equipment Fabrication. Complete catalog showing the facilities and services of Goslin-Birmingham Manufacturing Co.

113A Valve Manifolds. Equa-Safe Valve Manifolds, made by Republic Flow Meters Co., stop damage to differential bellows and diaphragms. Bulletin.

114A Sealless Pumps. No stuffing box or mechanical seal to leak, contaminate, or require maintenance. Complete story from Vanton Pump and Equipment Corp.

115R Spiral Blade Mixer. Gives smooth, intimate blend without pile-up. Catalog from Paul O. Abbe, Inc.

116L Vertical Chemical Pumps. Lawrence Pumps, Inc. specialize in pumps for handling hot concentrated acids, corrosive alkalies, molten salts, molten sulfur, volatile semi-fluids. Consulting services.

118L Horizontal Plate Filters. Assembly specially designed with positive seal to prevent trapping of air. Sparkler Manufacturing Co.

119A Equipment Fabrication. Process equipment in all metals and alloys. Bulletin from Koven Fabricators, Inc.

120TL Skin Protection. "Kerodex" prevents irritation from epoxy resins, amine hardeners, solvents, cutting oils, etc. Ayerst Laboratories.

120BL Heat Exchange & Process Equipment. Manning & Lewis Engineering Co. offer design, engineering and fabrication services to the chemical process industries.

(Continued on page 76)

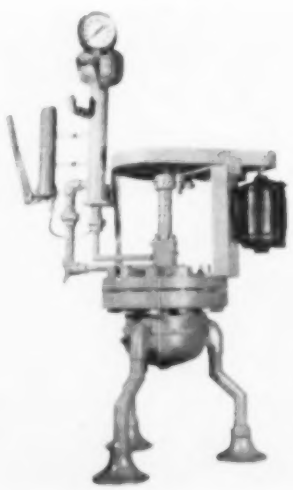
DEVELOPMENTS OF THE MONTH (*Cont.*)

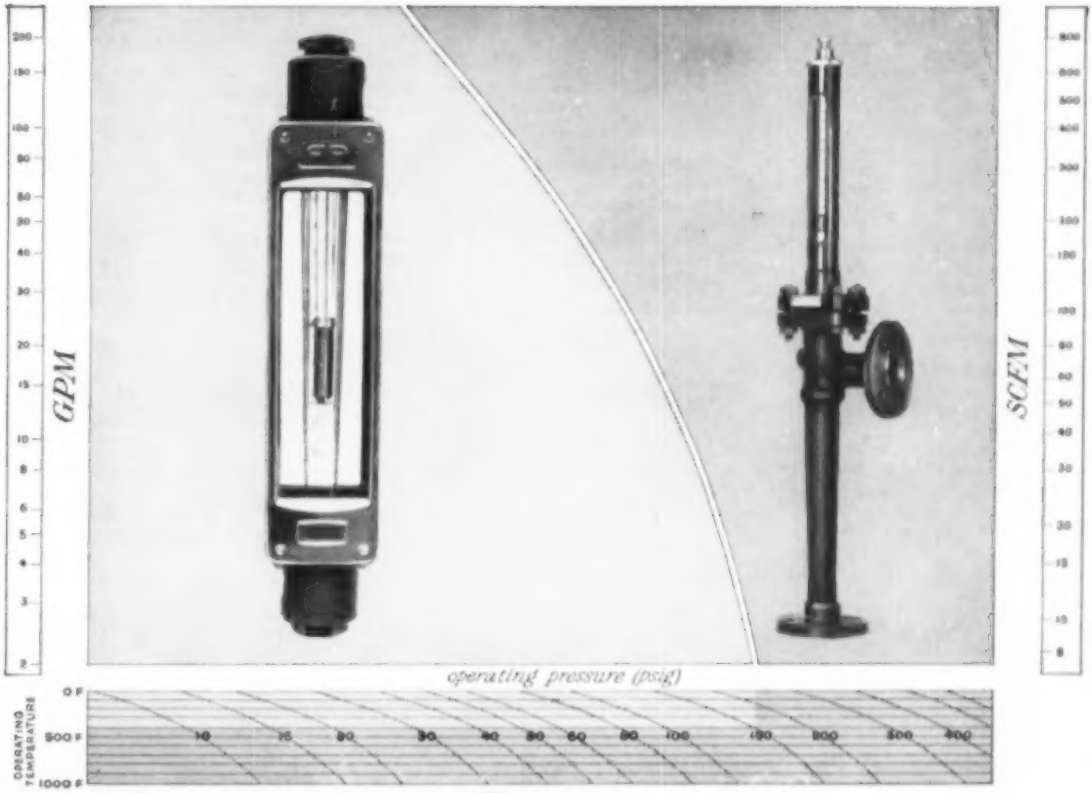
396 Glassed-steel Autoclave. A new, specially-designed autoclave which will handle reactions up to 750 lb./sq.in. is being offered by the Pfaudler Co.

Constructed of glassed carbon steel, the autoclave gives the corrosion resistance of glass and the structural strength necessary to withstand high pressures. Reactions can be conducted with internal pressures as high as 750 lb./sq.in.

A wide selection of agitation can be obtained from the variable-speed drive. Provision has been made for a thermometer well and the non-metallic rotary seal is equipped with pneumatic lubrication. Capacities are available from the manufacturer. Circle number 396 on Data Service Post Card.

(Continued on page 76)





For all flow measuring problems...

F & P HAS THE ANSWER

Corrosive fluids or gases, corrosive atmospheres, high temperatures and high pressures are common flow measuring problems in the chemical industry . . . and they're being solved every day with Fischer & Porter flowmeters.

Two of the most popular types of F&P flowmeters are the 1700 Series Flowrator meter and the all-metal Fig. 52 armored Flowrator meter. These versatile meters give you a predictable calibration performance in all ranges doing away with the necessity of individual calibration. You can get maximum corrosion resistance because both meters are available in many different materials.

Here are just a few of the features of the 1700 Series flowmeters that make them especially adaptable to the chemical industry:

Stainless steel enclosure standard Eliminates costly maintenance because corrosive atmospheres are no problem.

Three designs in one basic instrument Side plate construction gives extra rigidity and prevents operating stresses and strains from being transmitted to the tube . . . standard enclosure gives extra protection against accidental tube breakage . . . pressure enclosure gives maximum protection.

End fittings rotate 360° Simplifies piping.

Built-in panel mounting fittings Longer bolts are all that is needed for front or rear panel mounting.

Controlled outside tube diameter Permits the use of *molded* teflon liner and pre-cut packing rings interchangeable within meter size.

The Fig. 52 armored Flowrator meter is another favorite of industry. Here's why:

Cold-formed metering tubes Unique cold forming of precision-bore metal metering tubes eliminates price differential between glass tube flowmeters and all-metal flowmeters . . . assures complete interchangeability of metering tubes.

150 lb. and 300 lb. flanges standard Eliminates any problem in the matching of flanges.

Only one moving part Minimizes maintenance and pressure drop.

This is only part of the story on what F&P flowmeters can do for your process. To get all the details on 1700 Series and Fig. 52 Flowrator meters, write to Fischer & Porter Co., 1137 County Line Road, Hatboro, Penna.

Catalogs on other F&P flowmeters

10-A-10—Introduction to F&P Flowrator meters
10-A-43—High capacity Flowrator meters
10-A-93—Selection Guide for Flowrator meters

FP FISCHER & PORTER CO. Hatboro, Pa.

COMPLETE PROCESS INSTRUMENTATION

IA 1144B

PRODUCTS ADVERTISED IN THIS ISSUE (*Cont.*)

121A Glassed Steel Equipment. "Chemstor" Tanks bulletin and Dryer Blender data sheet from the Pfaudler Co.

123A Water Conditioning Equipment. Detailed information on aerators, degassifiers, deaerators available from Permutit Co.

124L Job Opportunities in Propellents. Physical chemists, metallurgists, chemical engineers, physicists, chemists wanted. Jet Propulsion Laboratory, Calif. Institute of Technology.

124BR Fused Quartz Data File. Standard apparatus, crucibles, trays, cylindrical containers, etc. Amersil Co.

125R Flexible Ball Joints. Barco flexible ball joints replace hose in many hazardous locations. Barco Manufacturing Co.

126L Filter Presses. Shriver Filter Presses cost less and require less floor space per unit of filtering capacity. Bulletin from T. Shriver & Co.

127R Flow Tubes. Gentile flow tubes, product of Foster Engineering Co., are impact type head meters for use as differential producers.

128L Silicone Defoamer. Dow Corning Corp. will send generous free sample of Antifoam B.

128R Steam-Jet Evactor Units. Can maintain absolute pressures down to 50 microns Hg abs. Croll-Reynolds Co.

129R Filters. Adams backwash design can lower your filter labor costs. R. P. Adams Co.

131R Aero Heat Exchangers. Sustained full capacity in cooling and condensing with no dependence on cooling water. Bulletin from Niagara Blower Co.

132L Filter Press Catalog. Complete with illustrations and specifications to help plan new filtration facilities. D. R. Sperry & Co.

132R Corrosion Resistant Plastics. American Agile Corp. is a dependable source of supply for processing equipment requirements. Literature.

133R Low Cost Rotary Pumps. The Eco All-Chem rotary pump is specially designed for severe corrosive service. Eco Engineering Co.

134L Fused Quartz Laboratory Ware. Illustrated bulletin from Thermal American Fused Quartz Co.

134R Water Treatment Systems. Ion exchange equipment is offered by the Illinois Water Treatment Co.

135R Chlorine Vaporizers. Richard M. Armstrong Co. builds standardized, heavy duty vaporizers for chlorine in the vertical design in capacities from 180 to 16,500 pounds per hour. Inquiries invited.

136L Metal Joints. In stainless steel or brass, large range of sizes. Ace Glass Inc.

137L Wood Storage Equipment. Equipment bulletin from Wendnagel & Co. describes wood processing and storage equipment.

137R Thermocouple Insulators. 4-page bulletin gives specifications and ordering data. Claud S. Gordon Co.

138L Filtration and Agitation Equipment. New complete catalog available from Alsop Engineering Corp.

138R Centrifugal Pumps. Enclosed and open impeller types. Bulletin from Frederick Iron and Steel, Inc.

139TL Laboratory Glassware. Full information on the Diamond D Blue Line available from Doerr Glass Co.

139BL Bin Level Indicator. New motor-driven, paddle-type for automatic bin level indication or control of bulk materials. Details from the Bin-Dicator Co.

145TL Advanced Design Spray Nozzles. Comprehensive catalog from the Spraying Systems Co.

145R High Pressure Compressors. From single stage to six stages, from 125 to 25,000 lb./sq.in. Catalogs from Norwalk Co.

146TL Pilot Plants and Processing Equipment. Consulting services available from Artisan Metal Products Inc.

146BL Adjustable Sprocket Rim. The Babbitt sprocket rim with chain guide simplifies pipe layout, fits any size valve wheel. Catalog sheet and prices from Babbitt Steam Specialty Co.

154TL Vacuum Equipment. Steam jet ejectors, condensers, other vacuum equipment. The Jet-Vac Corp.

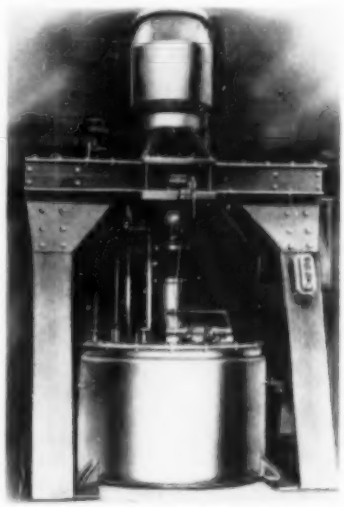
154BL Indicating Pyrometers. The Simplytrol indicating pyrometer has twenty-one ranges for temperature. Accuracy 2% of full scale. Assembly Products, Inc.

DEVELOPMENTS OF THE MONTH (*Cont.*)

397 Automatic Suspended Centrifugal. A completely automatic suspended centrifugal for the chemical, pharmaceutical, and food processing industries is being produced by the Centrifugal Division of the Fletcher Works.

The machine comes in sizes ranging from 20 to 48 inches, and is said to be the first fully-automatic equipment of its kind that can operate at a uniform speed, produce a uniform product with each cycle yielding identical quality and quantity. Operation can be either by hydraulic or electric drive motor as required.

The fully automatic operation of the Fletcher suspended centrifugal line will permit one operator to direct the activity of any entire bank of fully-automatic centrifugals. Circle number 397 on Data Service Post Card.



139R Flow Rate Regulators. Technical bulletin from W. A. Kates Co. gives all details on the Kates single-unit flow rate regulator.

140B Chemical Plant Layout System. Brochure with complete details of three-dimensional process and chemical plant layout. "Visual" Plant Layouts, Inc.

141TL Precision Bore Stirrers. Bulletins on stirrers and precision bore tubing. Wilmad Glass Co.

141BL Rotameter Bulletin. Data on application, construction, materials, installation and operation. Schutte and Koerting Co.

141R Varidrive Bulletin. Varidrive gives a mixer its full potential of performance, avoids purchase of extra mixers. U. S. Electrical Motors.

144L Industrial Water Supply Systems. Collectors, galleries and intake systems. Ranney Method Water Supplies, Inc.

155BM Technical Guides. Technical books and manuals on various subjects. Ronald Press Co.

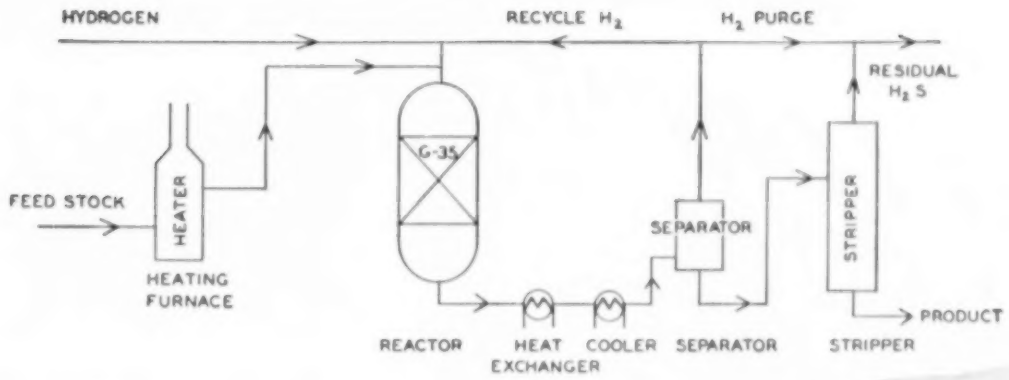
154BR Automatic Weighing Equipment. Single weighing units and fully programmed installations. Glengarry Processes, Inc.

155TR Thermo-Panel Coils. Replaces pipe coils. Bulletins with technical data, design and price information. Thermo-Panel Coil Division, Dean Products, Inc.

155BR Batch Mixers. 100 to 8,000 lb. per batch. Literature from H. C. Davis Sons' Mill Machinery Co.

IBC Controlled Volume Pumps. Serve as flow controllers, ratio controllers, or final control elements. Application data from Milton Roy.

OBC Mixing Bulletins. Latest mixing information and full description of Lightnin Mixers. Mixing Equipment Co.



Naphthas, middle distillates, gas oils and lube stocks can all be upgraded by hydrogen treating with the use of new Girdler G-35 catalysts. These highly active cobalt molybdenum catalysts were developed specifically for the desulfurization, denitrification and stabilization of petroleum feedstocks covering a wide molecular weight range. Typical flow diagram is shown.

Check these outstanding benefits of G-35 hydrogen-treating catalysts

G-35 HAS OUTSTANDING PHYSICAL PROPERTIES — these are retained even after extended use. Permit outstanding operational flexibility, continuous economical operation with essentially 100% yields.

IMPROVEMENT OF COLOR stability, lead susceptibility, burning characteristics and the removal of poisons from catalytic reforming feedstocks are among the more important results achieved. Girdler's expanded production facilities are geared to meet your needs for G-35 catalysts.

DETAILED INFORMATION is available on G-35 catalysts. Bulletin GC 304 discusses applications, gives process conditions for various distillate stocks, performance features and typical catalyst specifications. Free on request.

CATALYST DEPARTMENT

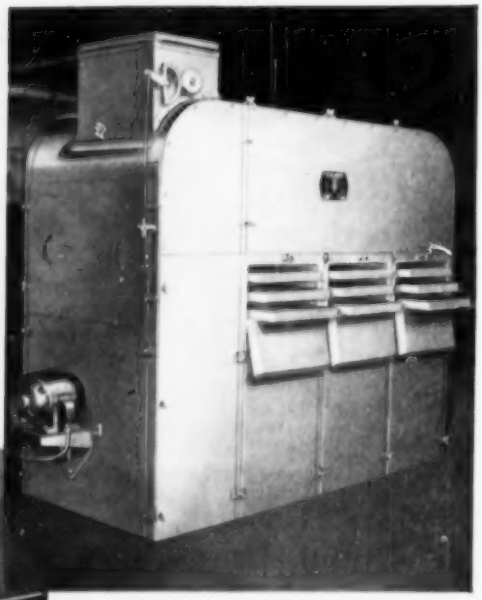
The **GIRDLER** Company

A DIVISION OF NATIONAL CYLINDER GAS COMPANY

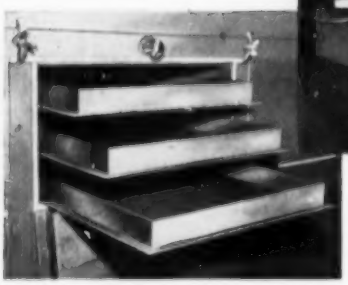
LOUISVILLE 1, KENTUCKY

GIRDLER MANUFACTURES CATALYSTS FOR: HYDROGENATION • SYNTHESIS GASES AND HYDROGEN GENERATION • DESULFURIZATION • NEW CATALYTIC PROCESSES

TRAY DRYING AT ITS BEST! by SARGENT



9-tray Sargent Dryer for reclaimed rubber. Equipped with explosion-proof latch so that door in back simply opens should pressure build up within the dryer. Installation in large chemical plant.



Pilot Plant Sargent Tray Dryer — 3 trays, even circulation of air over and through all trays. Air flow may be adjusted to product needs easily and quickly. Installation in food plant.

There's a Tray Dryer by Sargent to do the job. From one tray to dozens; from small table or lab models to huge, multi-stacked, multi-tray jobs; from s-l-o-w drying cycles for sensitive or unstable materials to high-speed drying where "flash" methods are indicated.

All are of Sargent's famous dependably sturdy and trouble-free design and construction; completely automatic operation with simple changeover to manual for small test or research runs; fully instrumented; Guaranteed performance and complete product control; product protection with uniform quality results every charge. All are performance-proven with a wide variety of products — from abrasives to waste sludge.

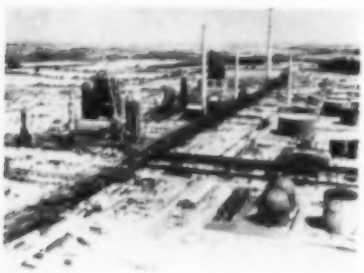
A Sargent Dryer will do the job for *your* product — better, easier, at less cost. Want details? Just ask your nearest representative or write or phone us.

C. G. SARGENT'S SONS CORPORATION

Graniteville, SINCE 1852 Massachusetts

PHILADELPHIA 19 — F. E. Wesson, 519 Murdock Road
CINCINNATI 15 — A. L. Merrifield, 730 Brooks Avenue
CHARLOTTE, N.C. — W. S. Anderson, Carolina Specialty Co.
ATLANTA, GA. — J. R. Angel, Mortgage Guarantee Building
TORONTO 1, CAN. — Hugh Williams & Co., 27 Wellington St. East

INDUSTRIAL NEWS



The largest alloy fabricating project ever undertaken is Flori Pipe Co.'s contract for the substantially all alloy piping of this giant new Tidewater Oil refinery 15 miles south of Wilmington, Del. In this largest petroleum refinery ever built at one time there are almost 250 miles of piping, and included in this total are the 1,500 tons of fabricated alloy piping delivered by Flori to prime contractor C. F. Braun & Co.

Multi-million-dollar carbon and synthetic graphite plant under construction by Crescent Carbon Corp., a subsidiary of Crescent Corp., between Rosamond and Lancaster, Cal., is nearing initial testing and operation. The plant, which will produce carbon and graphite electrodes, anodes, electrolytic anodes, and other carbon and graphite products, is utilizing petroleum coke and pitch as principal raw materials. The completely equipped plant, one of the most modern in the world, is the first of its type to be constructed in the West. □

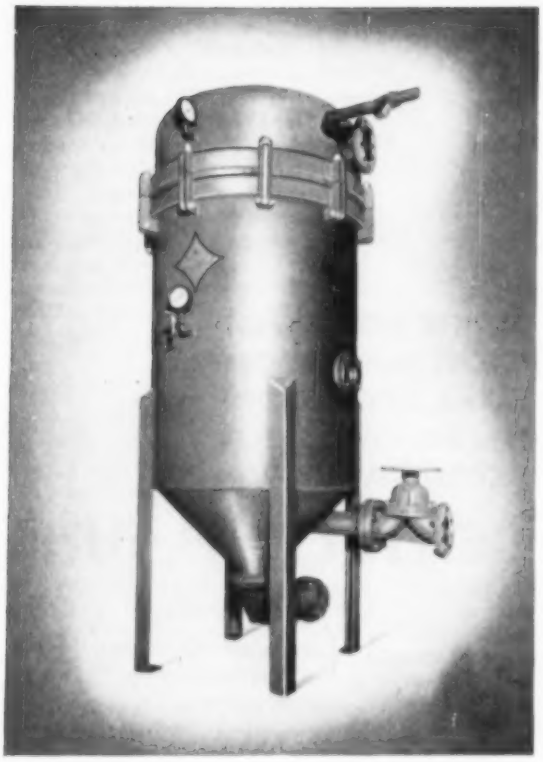
Modernization and addition of equipment at Olin Mathieson's HTH high-test calcium hypochlorite plant at Niagara Falls, N. Y., will increase the production of HTH by 25%, completion is scheduled for early fall. □

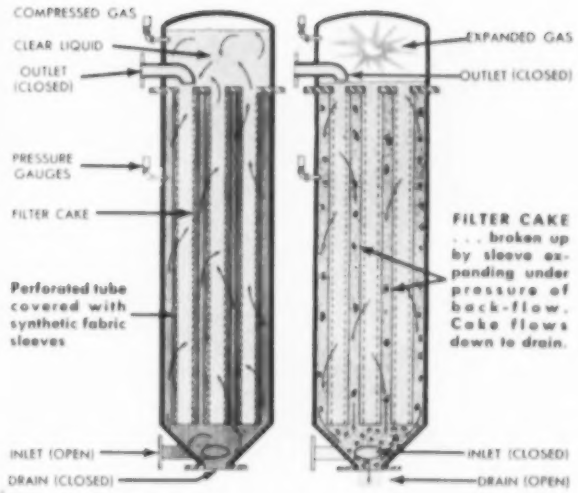
Phenol output will rise considerably in the near future. Both Monsanto and Barrett Division (Allied) have announced planned expansions.

Barrett's Philadelphia, Pa., plant will have nearly twice its original capacity when improved techniques developed in Allied's research lab are completely installed early in 1957. The plant will then be, according to Barrett, the largest and most modern phenol plant on the Eastern seaboard.

Monsanto, which already is the second largest phenol producer in the country (20% of total production) will increase its capacity 25% by the second half of 1958. □

Fluor Products Co., a division of the Fluor Corp., has formed a separate division to design, prefabricate, and market a complete line of cooling towers for the air conditioning and refrigeration industry. □





FILTERING PREPARING FOR HYDRA-SHOC **HYDRA-SHOC**

SELF-CLEANING *Hydra-Shoc** FILTER

PROVIDES EXTREMELY LOW OPERATIONAL MAINTENANCE DUE TO FASTEST CLEANING CYCLE AVAILABLE!

Industrial's new tubular filter creates own air pressure for fast self-cleaning in seconds . . . simply shutting off the outlet valve at the end of a filtering cycle prepares the filter for Hydra-Shoc cleaning. The air trapped in the filter chamber builds up under normal input pressure until a desired point is reached. Then a set of quick opening valves simultaneously shut off the inlet and open the drain. The air, suddenly released with a hammer-like blow, expands the fabric sleeves, instantly dislodging and driving the filter cake through the drain in seconds. You will find this Hydra-Shoc filter exceptionally good for low solids filtration—but remember . . . Industrial also makes Horizontal and Vertical Filters and our engineers can recommend without partiality a system most applicable to your process requirements.

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- Eliminates backflow pumps
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- Individual tube removal
- Positive, easy sludge removal
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PACIFIC NORTHWEST VACATIONLAND OFFERS EXTRA ATTRACTIONS FOR MAJOR A.I.Ch.E. MEETING AT

SEATTLE IN JUNE

Marshall T. Ramstad | Pennsylvania Salt Manufacturing Co. of Washington, Tacoma, Washington

Time—that will be the factor at Seattle. The best solution for realistic engineers will be to plan the summer vacation to include A.I.Ch.E.'s meeting and spend the rest of the vacation trying to do the impossible—see, sample, and enjoy all the Pacific Northwest has to offer during two weeks in June.

Best bet—drive out with the family. Come through Washington on the way West. See Spokane, the heart of the Inland Empire. And Grand Coulee Dam, with enough concrete in it to make a road three times around the world at the equator, and so vast it could use the Great Pyramid of Egypt as a ticket booth. After Grand Coulee turn left and head down for Richland where the Richland-Columbia Valley Section of A.I.Ch.E., co-sponsors of the Seattle meeting with the Washington-Oregon Section, will make you welcome and you can take a long look at the Hanford Atomic Plant (see page 82). After Richland take the highway past towering, snow-all-the-year-around Mt. Rainier to Tacoma, chemical center of the Northwest, and Seattle.

In Seattle you'll be bewildered—which way to go for the greatest vacation—after the technical sessions are over, of course.

Puget Sound

Perhaps you'll stay right in the Seattle-Tacoma-Puget Sound area. You won't make a mistake if you do. Heard about the city-dweller who dreams of jumping from his back porch into the water for a morning swim? You don't have to dream in Seattle. Everything for a vacation is right there.

Puget Sound itself is one of the great salmon fishing waters, salmon are there all year round, no season is closed. Swimming is ideal in such local spots as Hood Canal and Vashon Island. Boating here is more than sport, it's a way of life. Puget Sound and Lake Washington (fresh water lake right behind Seattle crossed by the longest floating bridge in the world) are literally the boating centers of the Pacific. Two hours from Tacoma is Mt. Rainier and skiing—in June! Are you a clam digger, picnicker, golfer, lounger on steamers cruising the bays and inlets? Right in the Seattle area you can find what you want.

If you're not the outdoor type at all, Seattle is a metropolitan city, has the museums, concerts, theaters, and the best seafood you could ask for. Salmon and steelheads aside, here are the Dungeness and King Crabs, the rock, butter and razorneck clams; Olympia and Willapa oysters; and many, many more unique, indigenous and magnificent types of seafood.

As for transportation, getting around in this area is easy. If you don't bring your car you can rent one. Highways go everywhere—no bouncing over back roads here.

The trouble with telling about Seattle-Tacoma is where to stop. There's a lot more you'll just have to see for yourself. And if you like to go farther afield, not much farther, you can center in Seattle and still go to all the outlying spots.

Rain Forest Primeval

Just two hours southeast of Tacoma is Mt. Rainier National Park. One of the most magnificent sights and parks in the world. Mt. Rainier itself is the hub, dominating the landscape for hundreds of miles with its 14,410 feet of snow-covered peak. Skiing is here, and sheer scenic grandeur, and the air of the mountains, and a photographer's paradise. But perhaps it is the hiking that is the best part of Rainier—if you are the real outdoor type. Fishing, too, of course, and glaciers, and wildlife in natural habitat. For the true adventurer, Mt. Rainier itself can be climbed, but it takes an expert. It is an extinct volcano and the climb is difficult.

Directly northwest is America's last frontier—the mountains and rain forests of Olympic National Park. One of the wildest areas left in the country, still unexplored in many parts, the mountains and forests are circled in a wide loop of impossible to describe scenery by Olympic Loop Highway. Drive around the area, or go in. You can't go in too far, but the thick, lush rain forests and the awesome mountains are worth a closer look. A riot of colorful wild flowers grows along

In Seattle, at A.I.Ch.E.'s June 9-12 National Meeting, after the day's high-powered technical sessions, the problem facing chemical engineers will be—where to begin to enjoy all the activities, the scenic grandeur, recreation and sports of the biggest vacationland near a major city in the country. It's like a process with a hundred equally attractive by-products—you really can't afford to neglect anything!

KLAHOWYA, TILLICUM!

IT'S CLOSER THAN YOU THINK

To Seattle from	Plane	Rail	Car
Chicago	8hrs.	37hrs.	4 days
New York	11hrs.	54hrs.	6 days
New Orleans	11hrs.	53hrs.	5 days

the highway and in the forests—this is another photographer's heaven. Of course, there is plenty of swimming and fishing along the way.

If it is ocean beaches you want, just take the highway southwest or west to the Pacific Ocean beaches. Olympic Beaches are directly west. Long Beach and Ocean Park-Klipsan are to the southwest. Accommodations are plentiful and of the best. There is clamming and surf fishing and some of the best swimming in the world on some of the best beaches—North Beach Peninsula itself is 28 miles of unbroken beach.

North are the San Juan Islands—177 volcanic islands, mostly uninhabited and a mecca for boaters, swimmers, picnickers. On the larger islands—Orcas, San Juan, Lopez and Guemes—there are resorts and hotels, old block houses, and some of the best inland salt-water swimming and fishing to be had.

Across the border to the nogth is Canada, Vancouver Island, and the cities of Vancouver and Victoria. Sumptuous, elegant and picturesque, Victoria is a vacation in itself. In both Victoria and Vancouver you can browse through shops filled with the best imported tweeds, old world china, and many other British products—including the treat of tea and crumpets in an English atmosphere.

Once again, of course, this just scratches the surface of the attractions of the Pacific Northwest. Farther afield there is the Columbia River, the Cascade Mountains, Indian Reservations where the Indians still live and carve their fabulous totem poles, the historical sites of the old sailing men who discovered the area, of Lewis and Clark, of the ill-fated missionary Marcus Whitman, of old Astoria, John Jacob Astor's fur-trading post, and so much more.

Chemical Center

Tacoma is the chemical center of the Northwest and Seattle isn't far behind. Much of the chemical activity is related to pulp and paper, but petroleum refining is large in the area. With natural gas now piped in, an even greater boom for the industry is expected. Both cities have large concentrations of the chemical industry and many plant trips are planned at the National Meeting.

In Seattle itself some chemical plants are: Monsanto, Reichhold Chemical, American-Marietta, Kaiser Gypsum. In Tacoma a sample is American Smelting & Refining, Pennsalt, Kaiser Aluminum & Chemical, Carstens Packing's fertilizer plant, Hooker, Stauffer Chemical. In Everett, there are Weyerhaeuser Timber and Scott Paper. At Hoquiam—Rayonier. At Anacortes—Scott Pulp & Paper and Shell Oil. North, in British Columbia, Hooker has just opened a chlorine-caustic plant. And so it goes, a center of the chemical industry in case you want a busman's holiday.

Planned Activities

The major technical program will include another important session on Chemical Engineering in the Pulp and Paper Industry (one of the largest opening-up-fields for chemical engineers, see *CEP* February 1957); a session on Electrochemical Engineering, long an important factor in Northwest industry where power is a prime inducement for industry; a sure-to-be useful-to-every-chemical-engineer session on Chemical Engineering Data

(Continued on page 82)

Salmon fishing on Puget Sound the year 'round.

One of the country's leading ski areas—Mt. Rainier.

At left, library at U. of Washington with Mt. Rainier in background.

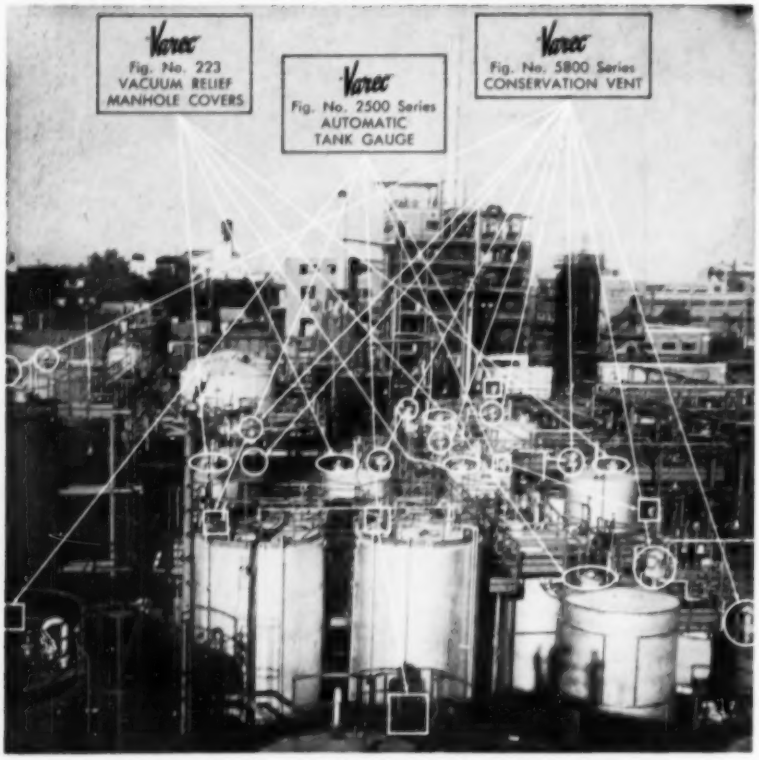

Photo — Courtesy of Barrett Division — Allied Chemical and Dye Corporation

GOOD MANAGEMENT Recognizes the Value of GOOD TANK EQUIPMENT

A glance at the above photo of the Philadelphia plant of the Barrett Division of the Allied Chemical & Dye Corporation reveals dozens of storage tanks equipped with "Varec" Conservation Vent Units, Pressure and Vacuum Relief Manhole Covers, and Automatic Tank Gauges.

Here is practical evidence of the important role "Varec" storage tank equipment plays in the industrial scene. "Varec" Figure No. 5800 Series Conservation Vent Unit affords the greatest protection for venting inflammable liquid storage. Flame Arrester, Figure No. 50, is listed by Underwriters' Laboratories for use on oil storage tanks and approved by Associated Factory Mutual Laboratories for use on chemical storage.

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961-19

SEATTLE MEETING

(*Continued from page* 81)

and Calculation Methods; a basic symposium on Filtration; and a thought-provoking session under AEC's Kaufman on Industry's Role in University Programs on Nuclear Engineering. Plant trips are still in the planning stage, but they will be there.

Appetite Department

A unique treat for meeting visitors will be a special "salmon bake" arranged by the Committee. It will be held at beautiful Kiana Lodge across Puget Sound from Seattle, will be reached by a boat trip across the Sound.

Of course, there will be luncheons and dinners where you can meet your friends, discuss shop or just talk as you wish.

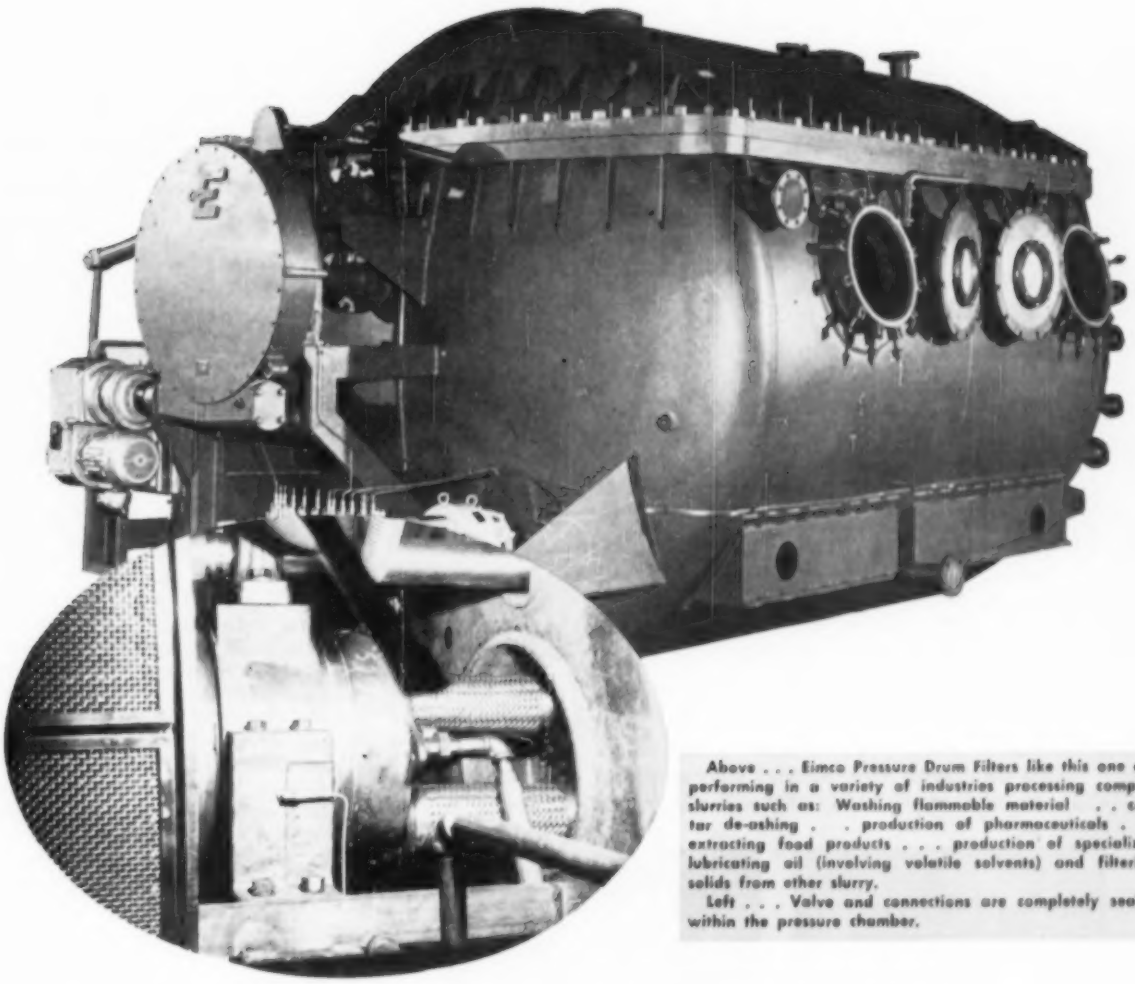
For the ladies, Seattle's meeting will be a big one. Among other things, a boat trip is planned through Lake Washington, Lake Union, the Government Locks, and around Puget Sound. A bus trip through the city is on the agenda, as are cocktail parties, get-togethers, and a lot more if the ladies can tear themselves away from just looking at the beauties of the Pacific Northwest.

Climate and Clothing

Seattle-Tacoma has a mild climate, not too hot and not too cold. Just plain

(*Continued on page* 84)

Pictured above is one of the production units at the Hanford Atomic Plant where plutonium is produced on an industrial scale. Below, a chemical separations plant at Hanford extracts plutonium from irradiated fuel elements behind thick concrete walls.



Above . . . Eimco Pressure Drum Filters like this one are performing in a variety of industries processing complex slurries such as: Washing flammable material . . coal tar de-ashing . . production of pharmaceuticals . . . extracting food products . . . production of specialized lubricating oil (involving volatile solvents) and filtering solids from other slurry.

Left . . . Valve and connections are completely sealed within the pressure chamber.

Here Are 5 Major Process Conditions...

where correct application of Eimco Pressure Filters will get you appreciable advantages:

(1) Where vapor pressure of the liquid at the filter feed temperature is too high to permit the efficient use of vacuum . . . **(2)** Where liquid viscosity is high (generally 100 centipoises or more) or solid particle size is very small, requiring a driving force greater than one atmosphere to get economic filtration rates . . **(3)** Where large labor savings and lower operating costs justify higher initial expenses . . . **(4)** Where employment of a valuable or high temperature gas for the production of a dried cake product is feasible . . . **(5)** Where filtration of saturated solutions results in excessive crystallization with a reduction in temperature or pressure.

Whether you are pre-planning for filter installations to handle new processes or are seeking to improve present operations . . . these are some of the general conditions that justify an investigation into **Eimco Continuous Pressure Filter Equipment.**

Submit your problem to the Eimco Research and Development Center, Palatine, Illinois. They have complete facilities to test your slurry on all types of filtration equipment to assist you in selection of a proper unit.

After exhaustive tests, if research shows that pressure filtration can be correctly applied to your problem, you will find that Eimco Pressure Filters offer you production (and profit) advantages.

Whatever your filtration problem, let Eimco's competent research facilities go to work for you. Write today!

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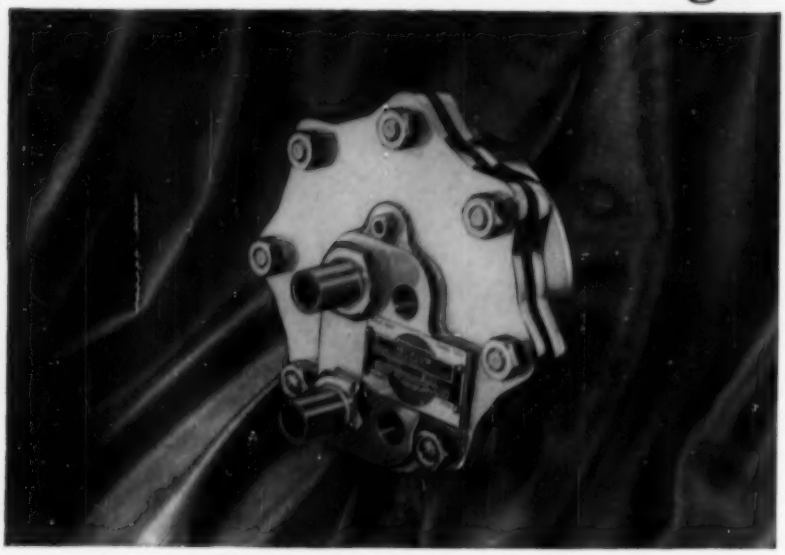
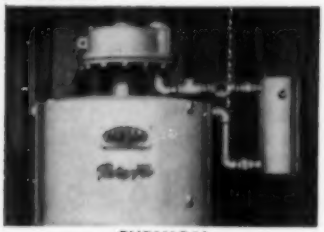
The SOLID GOLD Heliflow® Heat Exchanger



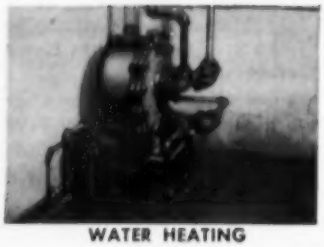
Actually we've never built one. But should your heat exchanger job require it, HELIFLOW® *can* be built of gold —solid gold.

And no matter how special your problem may be, the chances are that HELIFLOW® will offer the most favorable solution.

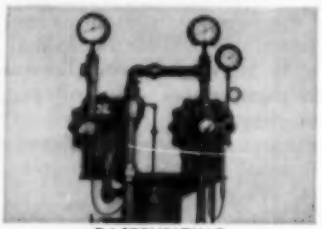


CHEMICAL

GLAND SEAL COOLING



WATER HEATING



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SEATTLE MEETING

(*Continued from page 82*)

wool suits for the men will be fine, slacks and a sweater are good. Topcoats can be useful at night, particularly if you are out on the Sound, which you probably will be. Spring is the season to prepare for, informality is the rule.

Ideal Vacation

There may be a better way for a chemical engineer to spend his vacation—but why try to think of one? The technical program speaks for itself, the plant trips should open a lot of eyes, and where could you find a better area to enjoy a vacation in?

Since Vancouver discovered Puget Sound in 1792, the entire area has been coveted for obvious reasons by many countries. When you come to Seattle you'll know why the Americans wanted to fight rather than accept any border lower than 54-40! And why the British were just as anxious that the border be the Columbia River. (Like good neighbors we didn't fight and we didn't get 54-40, but the British didn't get the Columbia River line either. We compromised, and we got Washington. Looking at this fabulous area now, we imagine the British might sometimes wish they had decided to fight!)

But the British didn't get Washington, we did, and now the Washington-Oregon Section of A.I.Ch.E. is offering it to the chemical engineers. As a local citizen informs us, the proper words are "Klahowya Tillicum," or "Welcome friend" in Chinook.

Commercial production of unsymmetrical dimethylhydrazine is now underway at Olin Mathieson's Lake Charles, La., plant. Operated by the company's Industrial Chemicals Division, the plant also produces hydrazine hydrate, anhydrous hydrazine, and other hydrazine derivatives. Unsymmetrical dimethylhydrazine is a strong reducing agent useful as aviation fuel, as an oxygen scavenger, and as an anti-skinning agent in paint. Although chemically very reactive, it can be handled safely by observing ordinary precautions for flammable or corrosive liquids. □

Construction will start immediately on a new plant to manufacture refined as well as technical grade sodium CMC (sodium carboxymethylcellulose) at Du Pont's Carney's Point Works in New Jersey. Completion will be early in 1958. □

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United States Gasket Company—pioneers and leaders in the fabrication and application of TEFLON*, KEL-F†, Nylon and other Engineered Plastics—now will be known as *United States Gasket Company, Plastics Division* of *The Garlock Packing Company.*

The U.S.G. sales organization of plastics specialists has been integrated with the 125 Garlock salesmen at 30 sales offices and warehouses, strategically located in the principal industrial areas of the United States and Canada. The assistance of these men and large stocks of our products are now as near as your telephone.

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*duPont trademark †Kellogg trademark

United States Gasket *Plastics Division*

OF THE GARLOCK PACKING COMPANY

The future of RAW MATERIALS for the ORGANIC CHEMICALS INDUSTRY

H. A. Mitchell and R. L. Kittle

Shell Chemical Company,* New York City, N. Y.

Although wood fractions, such as lignin and other by-products of the pulp and paper industry offer promise as basic raw material sources, the exploitation of these materials is in its infancy.

The early organic chemical industry in the United States was established upon a basic agricultural economy. Agricultural, animal, and forest products constituted the only raw material sources. It is true that during the past twenty-five years we have experienced some growth in the utilization of these basic raw materials for the production of many chemicals. However, not only would these raw materials be unable to supply today's demand, but they cannot be expected to have a very significant position with respect to additional organic chemicals production in the future.

Agricultural Raw Materials

For economic reasons it is to be expected that agricultural materials such as sugar, molasses, grain products, and animal fats will of necessity become relatively less important as basic raw materials for organic chemical production.

A typical example of this change in end utilization is the present molasses situation.

Molasses has ceased to be of major importance for organic chemical production except in times of national emergency. For many years excess molasses was available for use as a raw material for ethyl alcohol production. However today, because of its value as a feed for livestock it has now assumed a value higher than its equivalent as an ethyl alcohol raw material. We find it taking a position of decreasing importance in production of ethyl alcohol.

The increased demand for wood and wood products in meeting building requirements and the need for additional pulp and paper products has had the effect of curtailing the use of forest products as a basic raw material for all but a limited number of naval stores.

It seems doubtful if these products will assume a place of major importance as organic chemical raw materials within the next decade. The production of tall oil is of major significance, of course, and can be considered an exception in this connection.

Fossil Raw Materials

The first major expansion of the synthetic organic chemical industry in the United States began shortly after World War I when the production of cyclic organic chemicals was initiated to replace the imports of synthetic dyes and medicinals which had been cut off as a result of the war. The war created a large demand for phenol for the manufacture of picric acid for military purposes and, following the close of the war, the availability of this phenol capacity proved an incentive to the increased production of phenolic resins. The glyceryl phthalate resins, now more commonly known as phthalic alkyd resins, were first introduced in the mid-20's and soon grew to substantial levels.

Coal

During this period the basic coal chemicals such as benzene, toluene, naphthalene, and phenol utilized in the production of most of these products were obtained solely from the carbonization of coal. As a result of the marked growth of coke production, a direct corollary of the increase in basic steel production and of course a measure of the growth of our industrial economy, adequate materials were available to meet the steadily growing requirements for these various cyclic-based products. However, the growth of organic chemical production during World War II created a demand for many of these intermediates far in excess of the availability from coal carbonization.

Under present conditions, coal is carbonized for the primary purpose of making coke, and an economic operation can be realized only when the coke so produced can be disposed of as a premium material.

Coking plants cannot be operated economically to produce the various cyclic raw materials as primary products unless a major change in the value of these materials is to be realized.

Hydrogenation and direct gasification of coal are new processes under study and they may well develop into major operations over the next twenty-five years. However, it appears unlikely that either will produce appreciable quantities within the next ten years.

Increased requirements for aromatics have brought about changes in which petroleum-based materials have supplemented the cyclic derivatives of coal carbonization. As increased quantities of petroleum-based materials are utilized (the anticipated increase in requirements for many cyclic raw materials must come largely from sources other than coal) the coal-derived supplies will assume a position of lesser relative importance.

(Continued on page 89)

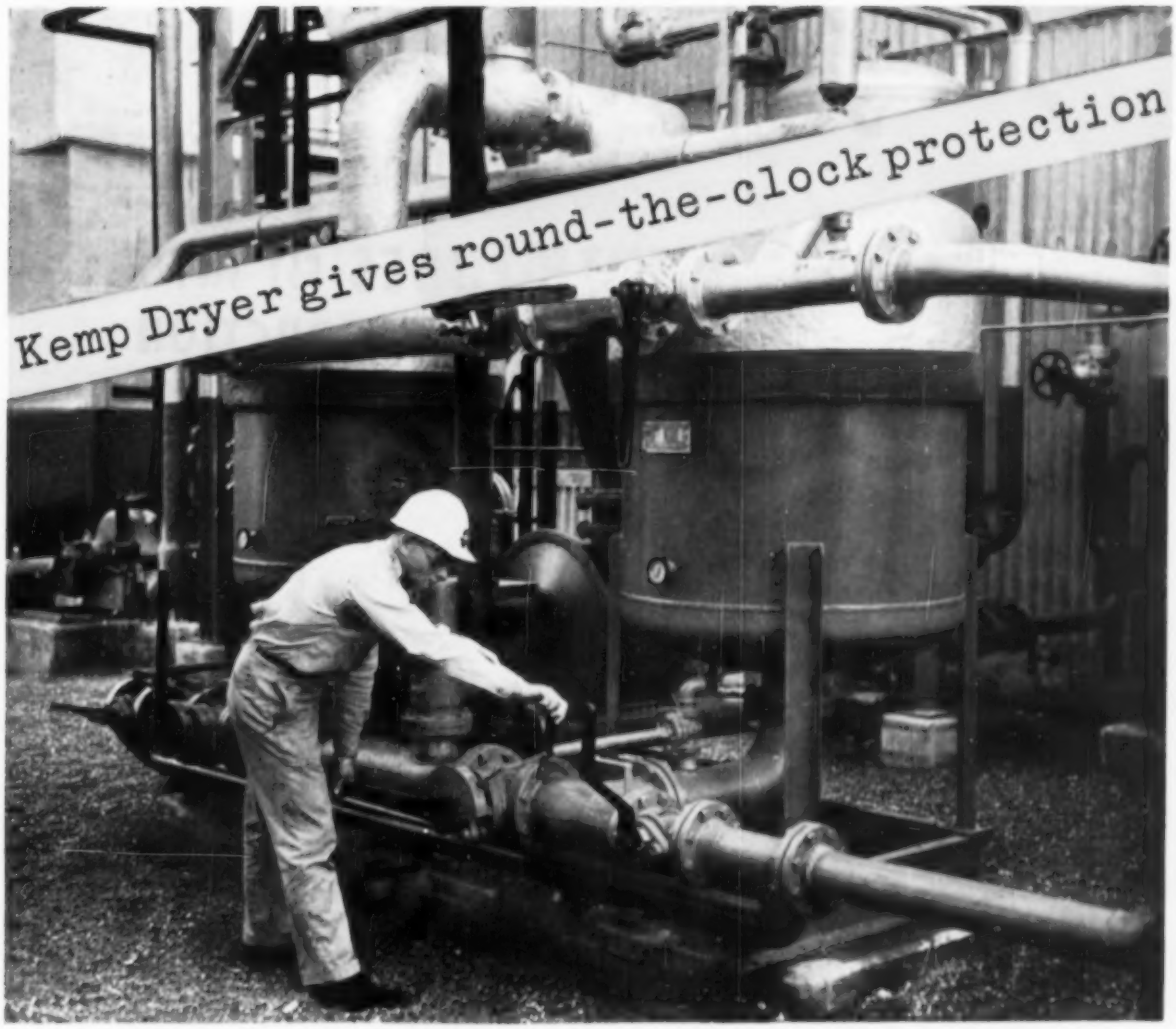
Table 1.

Benzene Production[1] and Requirements
(MM gallons/year)

	1945	1950	1955
Coke Oven Operations	126.7	154.5	174.2
Tar Distillers[2]	29.5	21.6	34.7
Petroleum	—	10.1	98.6
	156.2	186.2	307.5

[1] Nitration and other specification benzene.
[2] Including production from imported crude benzene.

* Mr. Kittle is Manager, Manufacturing Operations Department.



Grace Chemical Company Reports: *Kemp Dryer safeguards instruments throughout plant 24 hours per day*

The Grace Chemical Co. manufactures Anhydrous Ammonia and Urea 24 hours a day at Woodstock, Tenn. This operation demands instrument accuracy with a minimum of maintenance and downtime. To increase instrument efficiency by preventing corrosion and costly line freezes, Grace Chemical installed a Kemp Dryer.

Kemp Requires Little Attention

Semi-automatic, the Kemp Dryer works night and day drying compressed air for instruments and pneumatic controlled valves. According to operator Charles Lewis, the Kemp unit requires a bare minimum of attention.

Kemp Dryers for Every Purpose

Kemp offers a variety of dryer models to meet all problems. Designed to dry air, gases or liquids to sub-zero dew points at a low cost, they are constructed of quality materials and embody the engineering knowledge gained from Kemp's many years of experience. Kemp Dryers are available with manual, semi-automatic, or fully automatic tower reactivation. In addition, Kemp will prescribe the proper desiccant for each drying job. If you have a problem involving the removal of water from air, gases, or liquids, contact Kemp engineers now. For complete facts and technical information, write for Bulletin D100.

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Continuous centrifuge for separation of large amounts of solids from slurries, and for wet classification of solids.

SUPER-D-HYDRATOR

Completely automatic crystal dehydrator with external control of feed, rinse, and drying cycles.

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A clarifier or separator which automatically discharges liquids and comparatively dry solids.

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Heavy duty continuous solids discharge clarifier, separator and concentrator for high solids content slurries.

. . . and all seven of these Sharples types of centrifuges, including numerous additional variations, stand ready to serve you in the Sharples Process Testing Laboratories—these are full-sized machines capable of running your product under plant conditions.

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High capacity centrifuge affects clarification of liquids and separation of two immiscible liquids. Continuous liquids discharge.

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Provides highest centrifugal force of any commercial centrifuge (13,200 × G); clarifies liquids and separates two immiscible liquids.

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A continuous fine dry powder classifier combining high capacity, sharp separations, and high product recovery.

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RAW MATERIAL FUTURES

(Continued from page 86)

Petroleum

The phenomenal growth of the synthetic organic chemical industry during the last fifteen years has, to a very large extent, been based on petroleum-derived raw materials. It is estimated that approximately 2,500 different organic chemicals now trace their origin to petroleum or natural gas fractions, constituting more than 75 per cent of the total organic chemical production in the United States today.

For purposes of this evaluation, it is possible to divide the hydrocarbon raw materials into two basic categories:

- **those which serve as a supplemental supply to augment the availability from other sources, for example, petroleum-based aromatics such as benzene, toluene, ortho-xylene for phthalic anhydride, and cyclohexane for nylon; and**
- **those petroleum olefin raw materials which have brought into existence an entirely new class of organic chemical production by direct synthesis methods, such as ethyl alcohol from ethylene, and isopropyl alcohol and acetone from propylene.**

BENZENE

As an aid in the evaluation of petroleum-based raw materials in organic chemical production, consider the example of benzene. Benzene availability, prior to 1950, was largely restricted to that recovered from coal carbonization and the reprocessing of imported crude fractions. With the growth in benzene demand, stimulated by the synthetic rubber program during the 1940's and the increasing requirements in many other fields of cyclic chemicals, it became necessary to look to the petroleum industry for supplemental supplies, inasmuch as processes were available for the production of benzene, toluene, and xylenes from the respective naphthene precursors. These made possible the installation by the oil industry of benzene production facilities for 140 million gallons/year estimated capacity. The subsequent demand did not fully utilize this capacity during the early 1950's due in part to the continued availability of imported material. Table 1 shows clearly the growth in petroleum-derived benzene as compared to the increase in availability from other sources.

On the basis of published estimated benzene requirements of 530 million gal./year by 1965, it is apparent that additional petroleum-based production will be required. Depending upon the level of benzene imports and possible

(Continued on page 90)

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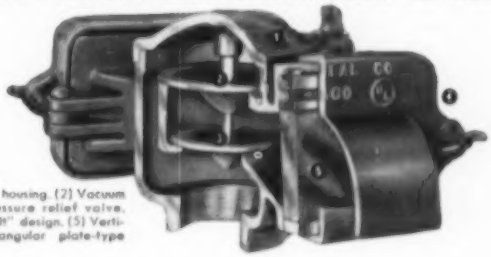

(1) Pressure-tight vent housing. (2) Vacuum relief valve. (3) Pressure relief valve. (4) Modern "swing-bolt" design. (5) Vertically mounted, rectangular plate-type flame arrester.

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White Sulphur report on

RAW MATERIAL FUTURES

(Continued from page 89)

changes in availability from coke production, the petroleum-derived requirement will lie somewhere between 275 and 325 million gal./year.

A question of primary importance is, "What is the *immediate* outlook for this quantity of benzene from petroleum?" If one assumes that only those refineries processing in excess of 75,000 bbl./day of crude oil find it economic to install benzene production facilities, the over-all potential at today's level of refinery operation is approximately 600 million gal./year. On the basis of a 1965 forecast of United States petroleum requirements of 10.5 million bbl./day and recognizing the trend to the construction of larger refineries, the 1965 forecast of petroleum-derived benzene will represent less than 40 per cent of the potential supply at that time, based on precursor availability. If past experience is any guide with regard to the petroleum picture, it is reasonable to assume that the oil industry is prepared to undertake the production of additional material. At the present time, substantial quantities are available and, although we must recognize the competitive effect of higher octane motor gasoline and the demands upon the individual refiner for these same higher quality products, it appears certain that the organic chemical industry's future requirements of benzene will be met.

Outstanding growth in the last five years has been experienced in chemicals derived from various petroleum olefins, such as ethylene, propylene, and butylenes derived from cracking of petroleum fractions in normal refinery operations. As usage has increased, the cracking of *selected* hydrocarbon fractions has been undertaken, and today a substantial portion of the hydrocarbon raw material required for organic chemical manufacture is produced in this manner.

To present an over-all view of the effect of hydrocarbon raw materials upon the chemical industry, it is desirable to review briefly the three primary raw material sources: ethylene, propylene and butylene.

ETHYLENE

The growth in production and utilization of ethylene during the last five years has exceeded that of any other single hydrocarbon raw material. Although data for 1956 production and usage are not yet available, on the basis of preliminary estimates of production of the three major ethylene derivatives—synthetic ethyl alcohol, polyethylene, and ethylene glycol—ethylene usage for 1956 is estimated to be in the order of 3½ billion pounds. The estimated distribution of 1955 production of these specific derivatives indicates, as follows, the extent to which this product has taken a basic place in the organic chemical industry:

Table 2.— Estimated Ethylene Demand for Major Ethylene Intermediates
(in MM Pounds of Ethylene)

Year	1950	1951	1952	1953	1954	1955
Synthetic Ethyl Alcohol	478	557	560	603	655	690
Ethylene Glycol	380	450	595	475	470	650
Styrene	167	219	217	248	218	315
Polyethylene	55	80	100	135	175	400
All Others	440	544	603	674	827	993
Total	1,520	1,850	2,075	2,135	2,345	3,048

Synthetic ethyl alcohol production for 1955, approximately 195 million gallons, was roughly 80 per cent of the total United States production of this essential organic chemical. Ethylene oxide production, and that of its primary derivative ethylene glycol, has grown consistently during the last five years to the extent that 1955 production of 888 million pounds consumed 650 million pounds of ethylene or approximately 21 per cent of the total usage.

Polyethylene production growth during the last five years bears out the optimistic forecasts made by producers of this versatile plastic. Additional facilities presently under construction will no doubt boost this product into a position as the major ethylene consumer within the near future. 1955 production in the order of 400 million pounds utilized approximately 13 per cent of the total ethylene production.

The use of ethylene in the manufacture of styrene, ethyl chloride, ethylene dichloride, ethyl bromide, and acrylonitrile accounts for the remaining major uses of ethylene.

The growth pattern of ethylene consumption and its distribution to major chemicals for the period 1950-1955 is indicated in Table 2.

On the basis of the growth pattern realized to date and taking into consideration new plants now under construction, ethylene usage of 6 billion pounds per year by 1965 does not appear unrealistic. Even though this quantity represents a major growth over that currently utilized, it represents but a minor portion of the potential material that can be produced by cracking recoverable ethane and propane from presently existing major natural gasoline plants and petroleum refineries. Taking into consideration the potentials from already existing plants and allowing for growth in petroleum requirements through 1965, an ultimate ethylene potential in the order of 35 billion pounds per year could be realized if maximum production were required.

PROPYLENE

Organic chemicals based upon propylene as a raw material do not cover as wide a range of products as those utilizing ethylene; however, they do represent a substantial portion of the synthetic organic chemical production. Isopropyl alcohol represents the largest single factor in propylene utilization and 1955 production approximated 650 million pounds of equivalent propylene. Isopropyl alcohol finds a major utilization in the solvents field as well as being the intermediate for the production of acetone, which alone accounted for 475 million pounds of isopropyl alcohol in 1955. Acetone, in addition to its use as an industrial solvent, is the starting point for the synthesis of a broad spectrum of higher boiling alcohols, ketones, and glycols.

The use of propylene in the manufacture of dodecene (tetrapropylene) and nonene represents the next major consumption. Dodecene is one of the basic raw materials for the manufacture of synthetic detergents; nonene for plasticizers and other plastics modifiers. Synthetic glycerine from propylene and synthetic resins based upon epichlorohydrin represent further uses. Although commercial scale manufacture has not been undertaken to date, it is anticipated that polypropylene will also find a place in the plastics field.

Based upon the 1955 production of its various derivatives, the utilization of propylene attained a level of 1.5 billion lb., equivalent to

(Continued on page 93)

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RAW MATERIAL FUTURES

(*Continued from page 90*)

approximately 8 million bbl. Although this represents a substantial raw material volume, it is only a small portion of that potentially available from petroleum refining operations. In the event additional material is required it can be obtained readily in many refineries where it is currently utilized in the production of motor gasoline blending stocks.

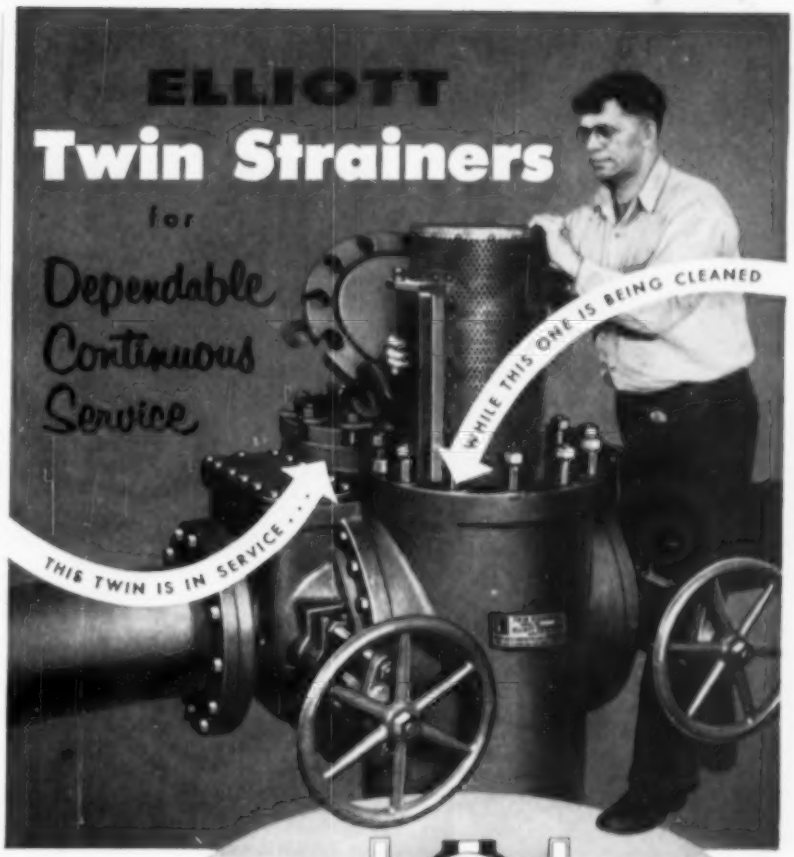
BUTYLENE

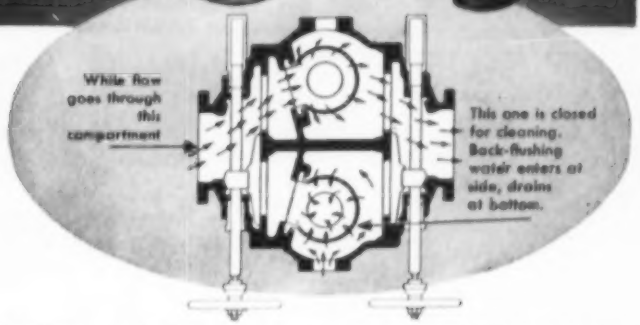
By far the most important raw material in the butylene group is normal butylene, used primarily for the production of butadiene for synthetic rubber, for secondary butyl alcohol and its derivative methyl ethyl ketone. The 1955 production of these products from petroleum sources consumed approximately 0.75 billion lb. of normal butane (3.6 million bbl.) and 1.6 billion lb. (7 million bbl.) of normal butylene. Isobutylene usage in the production of butyl rubber and various organic chemicals reached an estimated 125 million pounds (600 thousand bbl.).

Petroleum Industry—General

Although these quantities of individual hydrocarbon raw materials are extremely important in the over-all organic chemical production in today's industrial operations, the actual amount of material utilized represents approximately 2 per cent of the total liquid petroleum used in the United States today. While it is anticipated that the organic chemical industry will grow at a somewhat faster rate than the over-all petroleum usage, many other factors rather than hydrocarbon raw material availability will determine the trends that production follows. The development of new processes, the obsolescence of existing equipment, and the change in emphasis on end products will have a much greater effect upon the future organic chemical production than basic raw material availability. Successful growth in the organic chemical field is most likely for the company that is prepared to devote a maximum effort to research and development, one that is in a position to risk very large capital expenditures, and one with a marketing organization equipped to establish and maintain demands for high levels of production. At present it appears that much of the future growth will be based on petroleum raw materials.

Presented at A.I.Ch.E. White Sulphur Springs Meeting.




While flow goes through this compartment
This one is closed for cleaning. Back-flushing water enters at side, drains at bottom.

Twin Strainer with special back-flushing feature

Elliott Twin Strainers are built in two types. With Type A, one strainer basket is removed and dumped, while liquid flows through the other basket. Type A strainers are also built with a back-flushing feature, whereby the closed-off compartment is cleaned by reversing the liquid flow. Flushing and draining connections permit liquid to enter side of compartment, flow through basket and drain at bottom. Type V, with large-size baskets, is designed primarily for handling oil and viscous liquids.

For over 50 years, Elliott Strainers have been effectively removing objectionable solids from water and other liquids. The resulting trouble-free service has led to installations in power and industrial plants all over the country. Elliott also makes Single Strainers, one type having an Automatic Self-Cleaning feature, the other type with a removable basket for manual cleaning. For details call your Elliott District Office or write Elliott Company, Accessories Department, Jeannette, Pa.

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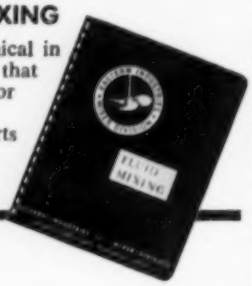

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Series A, extra heavy duty for large tanks, are available in side entering units only within a range of 5-30 H.P. with standard speeds of 280, 420, and 1150 R.P.M.

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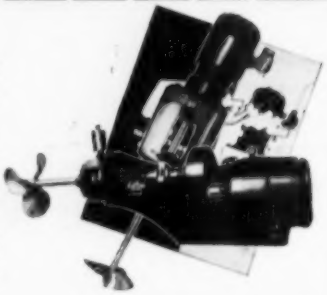

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NUCLEAR HEATING TECHNICALLY FEASIBLE?

Heating "without a speck of soot, an ounce of ash, or a cubic foot of smog" predicted by Hanford engineer.

Successful use of reactor waste heat in Hanford buildings has shown that dirt-free atomic heating is technically feasible, says S. L. Nelson, manager of one of the processing operations at the Hanford atomic plant.

At Hanford, water from the Columbia river is pumped through reactors used in producing plutonium. This water cools the reactor and picks up immense amounts of heat (along with a slight amount of radioactivity). The reactor water is then pumped to an outside heat exchanger, where it gives up its heat to an ethylene glycol-water solution. The ethylene glycol solution is circulated to air conditioning systems in reactor buildings, operations buildings, administrative offices, and maintenance shops.

Safety of the system is assured by maintenance of a higher pressure in the secondary ethylene glycol system than in the reactor coolant water. If a leak should develop, the flow would be from the non-radioactive fluid into the radioactive fluid, thus preventing radioactive water from getting into the heating system.

Technical Problems Simplified

Producing power with atomic reactors, said Nelson, involves many expensive problems which shrink to insignificance if low pressures, and temperatures below the boiling point of water, can satisfy the designer. While not worth much for driving a turbine, this range of heat does nicely for space heating, as in the new Hanford atomic energy heating system.

Success of such a program, emphasized engineer Nelson, depends on availability of atomic fuel for heating purposes, design of a reactor specifically for low-energy heat production, and overall reduction in costs of building and operating reactors.

A research reactor with exceptional safety and utility features will be constructed by General Atomic Division of General Dynamics Corp. at its John Jay Hopkins Laboratory for Pure and Applied Science in San Diego, Cal. The reactor will be a major tool in the laboratory's investigations in the nuclear energy field. □

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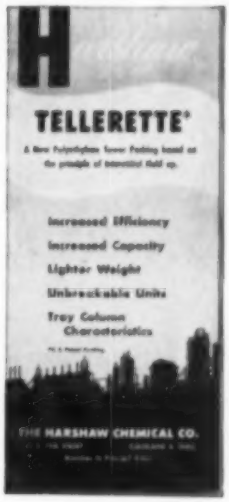

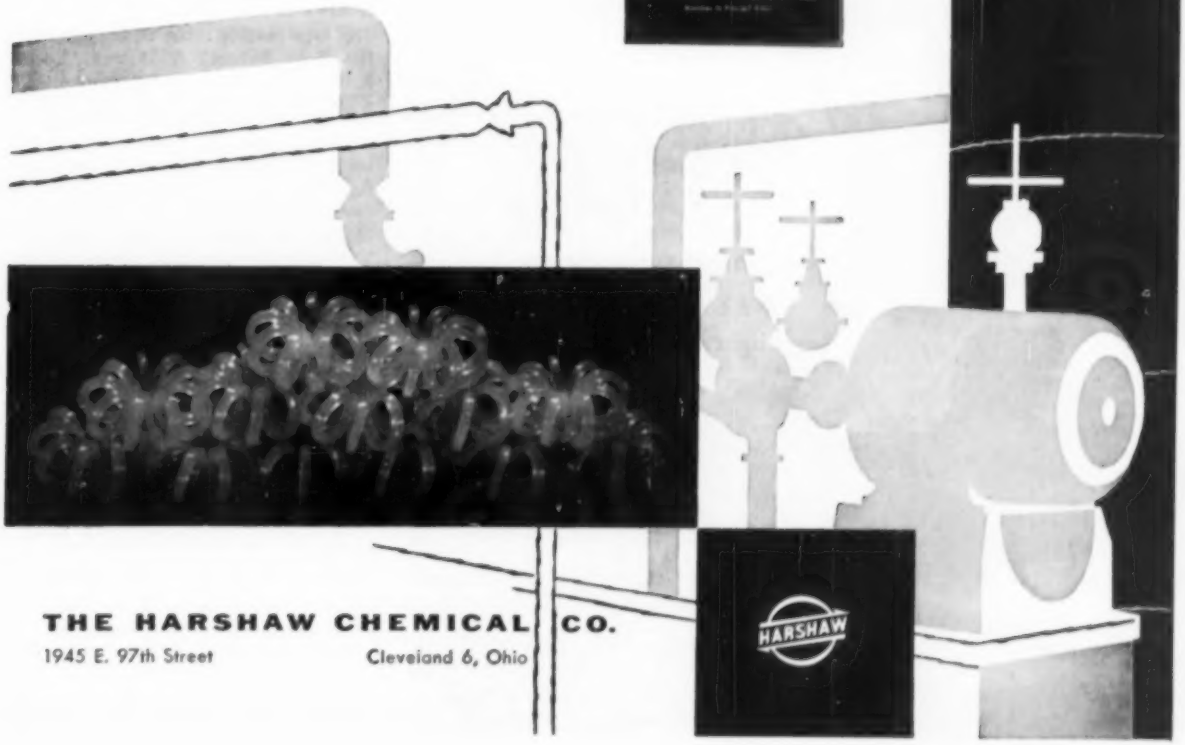

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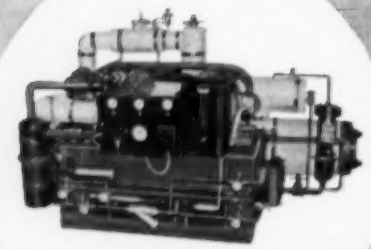

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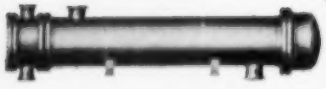

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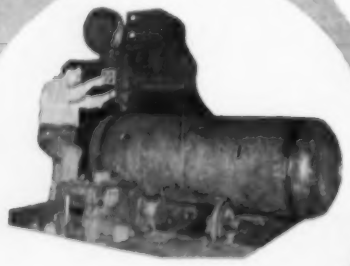

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NUCLEAR NEWS

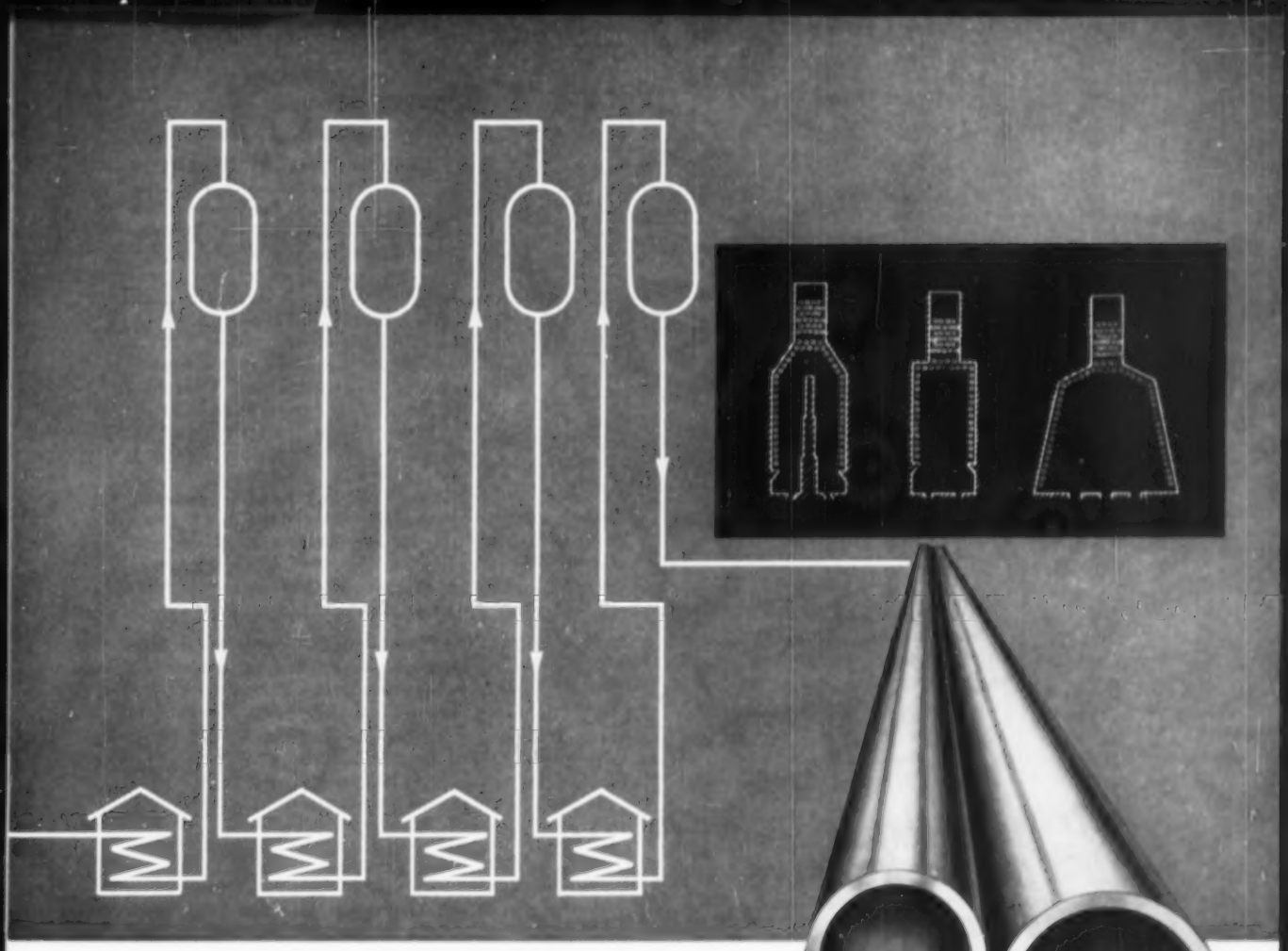
A 500-foot tunnel, 19 feet high and 23 feet wide, is the latest "method" being used to dispose of radiation-contaminated equipment at General Electric's Hanford Atomic Laboratory. An underground extension of a new chemical separations plant where uranium fuel is processed after being irradiated in nuclear reactors, the tunnel, about as big as a Pharoah's tomb, is fitted with spur railroad track and when a piece of heavy equipment is worn beyond use and too radiation-contaminated to be repaired, it will be loaded onto a flat car, rolled into the tunnel, and a concrete, water-filled radiation barrier gate will shut and entomb it. □

The first shipment of high-purity crystal bar thorium has been made from Metal Hydrides, Inc.'s pilot plant. With larger facilities in the design stage, Metal Hydrides is now ready to fill orders up to ten pounds each. The crystal bar thorium is produced by the Arkel-deBoer iodide process recently developed by Metal Hydrides in cooperation with Battelle Memorial Institute. The process yields thorium of the highest purity now obtainable. Thorium is expected to be important in the civilian atomic power program. □

A complete control system to control all reactor functions at all power levels will be built for the swimming-pool type reactor being constructed for Brazil by Babcock & Wilcox. Leeds & Northrup will build the system. □

A research program to investigate the use of natural uranium enriched with plutonium as a possible new fuel for atomic power plants is in operation at the Hanford installation operated for AEC by General Electric. The program is aimed at developing practical, low-cost methods of fabricating plutonium fuel elements, testing such elements in a small reactor, and subsequent reprocessing. The new fuel would eliminate the fact that many countries must build only reactors that operate on natural uranium or commit themselves to importing enriched uranium. It could also make it possible to net more power from a given supply of uranium. □

Contract for a preliminary technical and economic study of a mobile nuclear reactor power plant for possible application to locomotives has been awarded to Walter Kidde Nuclear Laboratories by Baldwin-Lima-Hamilton Corp. and Denver & Rio Grande Western Railroad. □



HOW MANY PROBLEMS IN THIS PICTURE?

Some layouts present a multiplicity of engineering, purchasing, warehousing and financing problems. Conceivably, (1) Return bends have to be designed for a perfect fit on their heater tubes, (2) Both tubing and fittings must meet the same exacting customer standards, (3) Simultaneous delivery must be made to guarantee erection schedules, and (4) Money tied up in material in process at any one time must be kept to a minimum.

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NUCLEAR NEWS

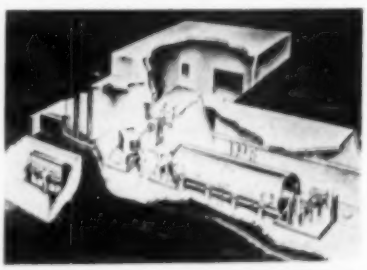
A $22-million plant at Henderson, Ky., to refine uranium ore and concentrates for sale to the Government is planned by Mallinckrodt Chemical Works and Climax Molybdenum Co. The joint plant is among seven proposals AEC has received for such plants. The plant will turn out uranium "feed" materials that, in turn, will be made by the Government into fissionable uranium reactor fuel. Operation will be on a unit price basis.

Climax will be majority owner of the joint company. Mallinckrodt is a pioneer in the development of the uranium refining process, currently operates a refining plant in St. Louis (see *CEP*, December, 1956), will operate a new $33-million government owned refining plant under construction at Weldon Spring, Mo. □

AEC has issued a license to Aerojet-General Nucleonics to operate its low-powered research reactor at San Ramon, Cal., after a pre-operational inspection by Commission Representatives.

Designated "AGN-201," the reactor is designed to operate at a power level of 100 milliwatts (0.1 watt). A compact, self-contained facility housed in a steel shell, the reactor is a prototype of reactors to be offered for sale to colleges, universities and other institutions for use in training and research. □

Ceramic fuel elements for atomic reactors are now being made by the Norton Company, Worcester, Mass. Molded of uranium oxide, the fuel elements are a new product although Norton has been making reactor control rods of boron carbide for some five years. □



This artist's sketch of a new type Van de Graaff particle accelerator shows the 10-million volt "atom smasher," highest energy Van de Graaff announced to date, as it will look when installed early in 1958 at the Chalk River facility of Atomic Energy of Canada, Ltd. (Canada's A.E.C.) The machine, called a Tandem Accelerator and designed and manufactured by High Voltage Engineering Corp., Burlington, Mass., will enable the study in continuous detail for the first time of the nuclear energy level of heavy elements which are known only in patches today.

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* *Pre-engineered, standardized Ross Exchangers cut months off normal engineering and manufacturing time.*

A report from the
White Sulphur Meeting

While cost is certain to go up, present short supply of labor could become a surplus within ten years, depending on who is looking at . . .

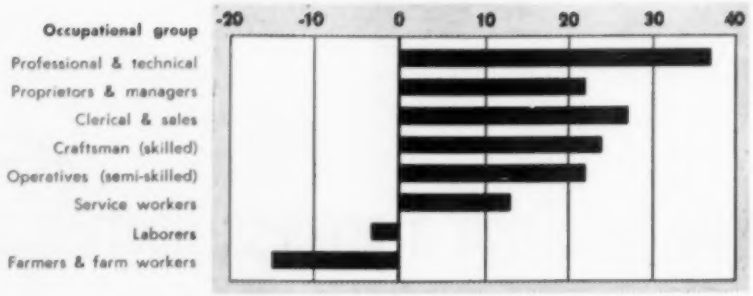


Fig. 1. Employment in major occupational groups. Per cent change, 1955-65. Our expanding economy demands more workers—better educated and better trained.

FUTURE LABOR TRENDS in the chemical industry

- Industrialist, labor leader, government statistician * agree the cost of labor is going up . . . up.
- Supply, already short, will continue so for the next ten years, says Department of Labor's statistics-watcher Wickens.
- "Not so!" counters labor's Knight, who worries about automation cutting into man-hour requirements, talks shorter work weeks with same (or more) take-home pay to maintain consumer buying power.
- Revealed: unions to put pressure on chemical industry (Knight). This will happen in 1958, says steel industry's Kirkpatrick.
- Question of engineer's remuneration debated by Knight, who "suggests" collective bargaining; and Kirkpatrick, who calls for management to re-evaluate engineers' jobs and pay larger increases as careers advance.

These and other points were covered in a lively symposium at A.I.Ch.E.'s Spring Management Conference. With a near capacity audience in the stately Greenbrier, chemical engineers in—or near—management heard that the shortage of "depression babies" will produce a dip in the availability curve for people between the ages of 25 and 34 by 1965. So says Labor Dept.'s Wickens, who advises hiring young and old, plus women, as a solution to the problem.

Oil & Chemical Workers' president O. A. (Jack) Knight disagrees, sees automation causing a labor surplus due to technological unemployment by 1965, expects reduction of work time to 30 hours a week at same take home pay.

Says Knight, "Our rate of productivity would permit shorter hours right now . . . there is general full employment and as long as this continues there will be no great pressure for a sharp reduction in hours . . . but manpower problems that come with automation will result in shorter hours, earlier retirement age, extended vacations. . . . Organized labor's long range goal is 30 hours a week with no reduction in take home pay."

Wickens takes sharp issue with Knight: "Automation is overrated. We have seen a bulge in automation and there now seems some sign of its leveling. Automation is just another phase of almost continual technological change going on for 150 years." Steel's Kirkpatrick agrees with Wickens that automation is overrated: "There will be displacement, temporarily, but people will be absorbed into other jobs gradually."

"The unique high degree of mobility which characterizes the American people," continued Wickens, "combined with the fast changes in our technology, will enable displaced workers to move readily into new occupations. The present large increase in service workers, such as TV repairmen, is an example of mobility taking advantage of the developments of our technology."

Basing her views on statistics of population, Wickens sees the opposite of Knight's views in 1965, sees the necessity of hiring older people, women and youngsters, *delaying* the retirement of older workers, to make up for the shortage of people in the 25-34 age bracket in 1965.

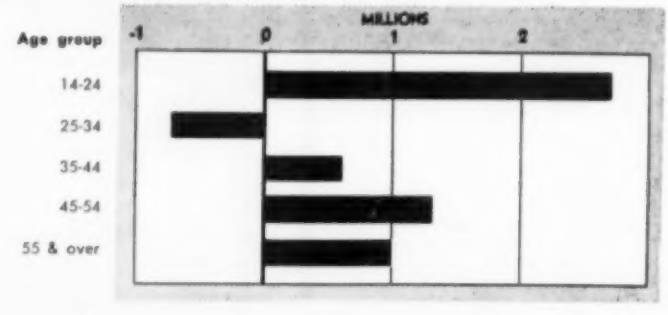
Labor—Rising Cost

With high employment levels and shortage of supply, Wickens sees increases in wages and fringe benefits to add to the cost of chemical production over the next decade. Kirkpatrick confirms this: "There is little, if any, chance that wage rates will move in any direction—except up."

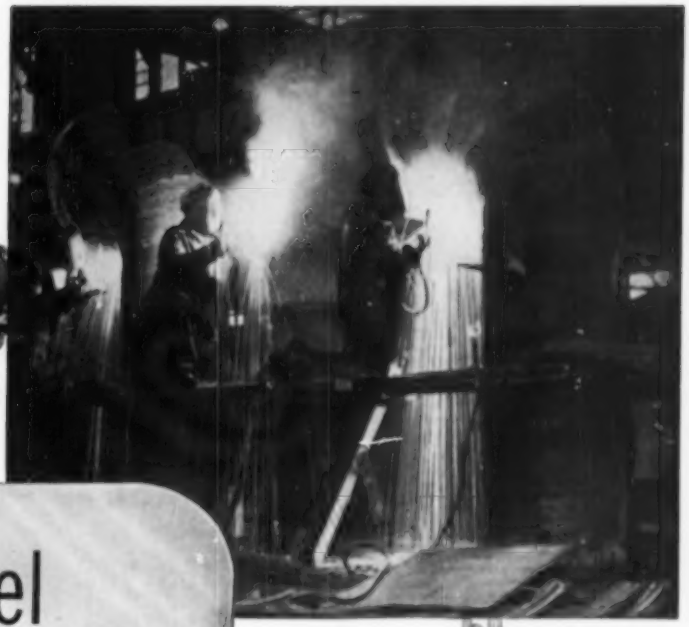
Knight had explanations: "In those fringe areas of the chemical industry where wages are too low to support a decent standard of living, organized labor will force wage increases in the reasonably near future . . . wages will increase as and when living costs increase . . . organized labor will press for and secure wage increases commensurate with increases in productivity . . . fringe benefits likewise will gradually increase . . . I predict that the time is near at hand when most fringe benefits will be paid

(*Continued on page* 102)

Fig. 2. Men in the labor force. Change in size of age groups, 1955-65. The male labor force will increase by 5 million. (Charts courtesy U. S. Dept. of Labor.)



* Symposium at A.I.Ch.E. White Sulphur Springs National Meeting. E. R. Smoley, The Lummus Co., chmn.; D. V. Brown, Sloan School of Industrial Management, MIT, presiding; F. H. Kirkpatrick, Asst. to the Pres., Wheeling Steel Corp.; A. J. Wickens, Deputy Asst. Sec. of Labor, U. S. Dept. of Labor; O. A. Knight, president, Oil, Chemical and Atomic Workers International Union (AFL-CIO).



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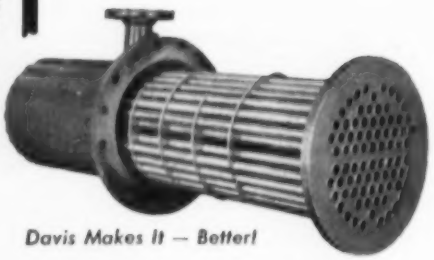

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Paracoil Type "P" Exchanger, 2-Pass Type, Stationary Head End. Tube bundle partially withdrawn, showing segmental baffles. Note close tolerances between tubes and baffles, and between baffles and shell. Close baffle tolerances assure higher heat transfer rates.

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FUTURE LABOR TRENDS IN CHEMICAL INDUSTRY

(Continued from page 100)

for entirely by employers, instead of partially by employees . . . (one reason: to avoid paying income tax on money first paid to employee, then paid into benefit funds)."

Union Picture

That labor's pressure is going to be felt in the chemical industry is the opinion of Kirkpatrick, who sees 1957 as a "cold war" year in preparation for high union demands in 1958. Major aim: to get employees psychologically ready to strike in 1958 if necessary, and to convince management that major strikes will be inevitable if they do not agree to union demands in large part.

Seeming to confirm Kirkpatrick, Knight said, "The intention of our union is to organize as many chemical workers as we can, anywhere, everywhere, and at any time we can." Knight went on to predict that the number of organized chemical workers will double within the next five to seven years, and the chemical industry may become one of the "patternmakers" of labor.

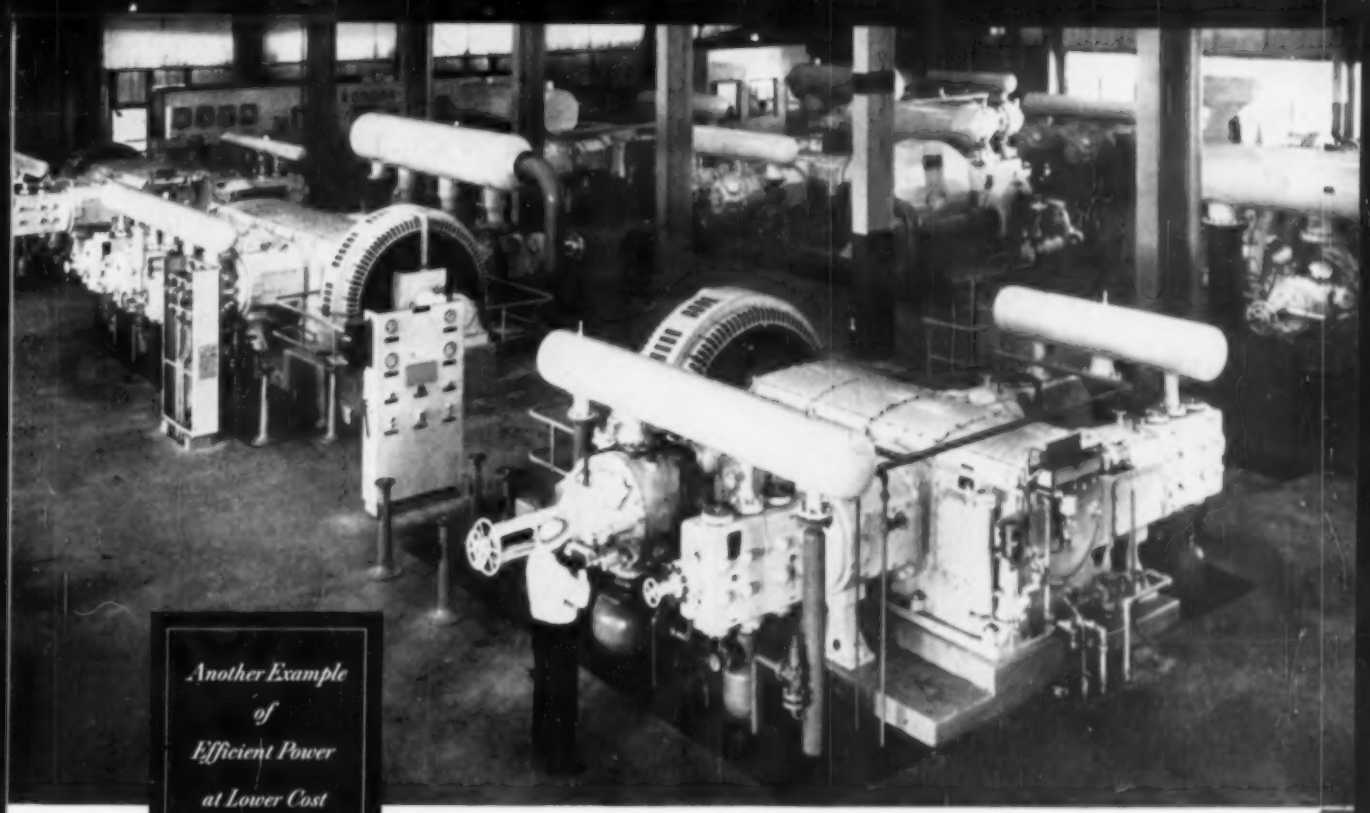
"Eventually, organization of chemical workers is going to be complete," said Knight. His own Oil, Chemical and Atomic Workers, he said, are at the present moment working closely with the International Chemical Workers Union (formerly the AFL union as opposed to Knight's CIO union, but together now in the big AFL-CIO merger) on some form of industry-wide bargaining unit to reduce battling among themselves. Any form of unity between the two unions would put them in a stronger bargaining position.

Industry's Kirkpatrick sees little chance of success in the near future in these attempts to unify the former union competitors. "Personal and political rivalries, power struggles, sheer inability to find enough high paying union jobs to go around, will keep the AFL and CIO pretty much of a paper merger." At the same time, Kirkpatrick sees little chance of significant Congressional labor legislation this year.

Engineer and Unions

Looking to 1965 for technical and professional people, Wickens said, "Non-plant workers in the chemical industry are expected to increase more rapidly than plant workers." Giving

(Continued on page 104)



Another Example of Efficient Power at Lower Cost

This over-all plant view shows several of the compact Cooper-Bessemer M-Line compressor units that deliver dependable performance in the Brea Chemicals, Inc. modern ammonia plant near Los Angeles.

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. . with Cooper-Bessemer JM Compressors

● Twelve Cooper-Bessemer JM compressors, totaling 17,500 horsepower, are doing an efficient, economical job of handling a wide range of compressor services in the Brea Chemicals, Inc. 13-million-dollar ammonia plant near Los Angeles.

JM-4's for air, ammonia, mixed gas, hydrogen and recycle service, and JM-6's handling nitrogen compression, offer important savings to this producer of 235 tons of ammonia daily.

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FUTURE LABOR TRENDS IN CHEMICAL INDUSTRY

(*Continued from page* 102)

figures, Wickens showed that while total employment in the chemical industry increased by about 14% from 1948 to 1953, employment of chemical engineers went up 45%, other scientists and engineers 62%. At present, 98% of chemical engineers are employed. "So far as shortages of chemical engineers are concerned," Wickens said, "it is likely that they will continue for several years to come."

With this heavy employment of engineers, and the present short supply, plus a definite relative decrease in the engineer's and other professional compensation, the engineer has come up with many problems (see Rusch article and NICB Report article in *CEP*, January 1957).

Kirkpatrick emphasized that engineers desire more pay but, along with it, they also want more professional recognition. Unions overemphasize the money problem, but management, felt Kirkpatrick, tends to underestimate the problem of professional recognition. "We've got to quit using engineers at low-skilled jobs. Management hasn't properly analyzed jobs engineers are assigned to," Kirkpatrick said. "We must take a long look at engineers' assignments and make sure they are given jobs commensurate with their training." In this regard, Wickens pointed to the ever-growing need for trained engineers and the waste that results from poor job assignment.

Knight was blunt: "The squeaking wheel gets the grease. The opinion I hold is simple: professionals should organize for collective bargaining." As for his own union's plans, and the details of any proposed professional organizing, Knight said it is still in the study stage—but it *is* under study in his chemical industry union. "If we find sufficient interest on the part of technicians and professionals, we intend to offer organizational opportunities to them."

Knight is not making idle conversation. Kirkpatrick emphasized that with the present professional and technical situation as it is [a shortage, a salary "squeeze," plus feelings of lack of recognition], "Companies are going to take a closer, a little more understanding, and a little more alarmed look at their white collar workers, their technical personnel, and in particular their engineers. The scramble for such people, with high starting salaries and then slow progression, is fertile soil for employee unrest."

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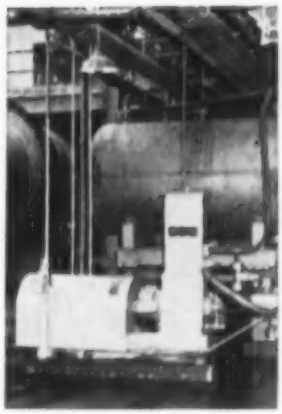
Send for details. For your tough pumping problems, it pays to specify Aldrich. Write for your copy of Data Sheet 100, a condensed catalog and selection table covering our entire line. The Aldrich Pump Company, 20 Gordon Street, Allentown, Pa.



This Aldrich Triplex Pump in explosives plant, pumps nitric acid at 185 lbs./min. against 400 psi maximum pressure. Aldrich Pumps are available in 25 to 2400 hp.

THE ALDRICH PUMP COMPANY

Spraco full-cone, free-flow nozzle discharging 860 gpm at 5 psi. This photo was taken at 1/5000 sec. shutter speed . . . at this speed the pulsations of the pump are apparent in the spray pattern.

RADICALLY NEW!

full-cone FREE-FLOW *nozzles from* SPRACO

Spraco's totally new, full-cone free-flow nozzles have been specially developed for high capacity, low pressure installations where clogging is a problem and full-cone spray pattern a necessity. Streamlined internal vane construction, with maximum vane openings, offers minimal flow resistance, virtually eliminates clogging.

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INSTITUTIONAL NEWS

Industry has again widened the scope of its hunt for engineering graduates. Figures released recently from the Carnegie Institute of Technology Bureau of Placements indicated a marked trend on the part of industry into the field of recruiting Ph.D. candidates, apart from M.S. and B.S. This drive for engineers in the Ph.D. field is accompanied by a significant rise in the number of students entering the graduate field of study. With the consistent shortage of engineering students and the increased number of students entering graduate studies, the companies have not only been forced to recruit harder and longer, but at a new and higher level. □

Two summer Intensive Courses in Automatic Control will be held at the Univ. of Michigan College of Engineering June 17 to 22 inclusive, and June 24 to 26 inclusive. April 15 is closing date for registration, and the courses are intended for engineers who wish to obtain a basic understanding of the field but have little time in which to do it. □

A two-day conference on high-temperature materials will be held April 16 and 17 in the Hotel Carter, Cleveland, Ohio. Sponsored by AIME in cooperation with the High-Temperature Committee of the Institute of Metals Division, the conference will be of particular significance to engineers working in the nuclear field, as well as in missile and aircraft work. □

A grant of $115,800 has been made by the National Science Foundation to the Oak Ridge Institute for Nuclear Studies to carry out an expanded Travelling Science Demonstration Lecture Program for 1957-58. Sponsored by N.S.F. in cooperation with the U. S. Atomic Energy Commission, which is contributing $38,000, this unique "travelling teacher" program is designed to stimulate interest in science and science-teaching careers on the part of secondary school students. □

National Nuclear Instrumentation Conference will be held in Atlanta, Ga., April 10-12. Sponsored by the Instrument Society of America, the conference will include sessions on instrumentation of nuclear power plants, several types of reactors, manufacture of nuclear fuels, unclassified military applications, radiation measurements, as well as application of nuclear instruments to industrial requirements. □

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W&T Liquid Chlorine Evaporators are designed for safety in keeping with good chlorine handling practice. For additional information write for Bulletin I-59.

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INSTITUTIONAL NEWS

A symposium on Chemical Reaction Engineering will be held in Amsterdam, Netherlands, May 7, 8 and 9, 1957, under the auspices of the European Federation for Chemical Engineering. □

A series of one-week resident lectureships for five of the country's most distinguished theoretical physicists is in progress at New York University's College of Engineering. Each of the five men will give three formal lectures open to the public at large free of charge. Julian Schwinger, Harvard, has already given his lectures on Field Theory, and Maurice Goldhaber, Brookhaven, has given his on Fundamental Particles. March 19, 20 and 21, Edward Teller, Univ. of Cal., will present his lectures on Nuclear Models. March 26, 27 and 29, J. C. Slater, MIT, will give his lectures on The Solid State. April 30, May 1 and 3, Subrahmanyan Chandrasekhar, Univ. of Chicago, will present his lectures on Astrophysics. □

New York University College of Engineering will conduct a program of 25 lectures on vacuum metallurgy from June 10 through 14, where specialists from the U. S. and abroad will discuss vacuum pumping systems, thermodynamics, specific processes, the design and operation of arc and induction melting systems, and applications of vacuum processed materials. The course is open to persons with a general engineering background including some metallurgy. Inquiries should be addressed to R. F. Bunshah, New York College of Engineering, University Heights, New York 53, N. Y. □

The nation's first comprehensive demonstration of systems now in use for the organization, storage and retrieval of recorded information, together with a symposium on information-handling problems and techniques, will be held April 15, 16 and 17 in Cleveland by the School of Library Science of Western Reserve Univ. (in conjunction with its Center for Documentation and Communication Research) and the Council on Documentation Research. □

48th Annual Meeting of the American Oil Chemists Society will be held at the Roosevelt Hotel, New Orleans, April 29 through May 1. □

Eleventh Annual Industry-Faculty Conference will be held at Louisiana State Univ., Baton Rouge, March 28 and 29, 1957. □

Crane plastic pipe licks acid corrosion problems for battery manufacturer

Metal pipe and fittings would last about 30 days in the battery test tanks of Globe-Union Inc., leading storage battery manufacturer. Sulphuric acid concentration would build up gradually until a destructive electrolytic action was set up with the metal piping materials.

Eighteen months ago, Crane polyethylene pipe replaced the metal pipe and fittings. Although in continuous use, recent examination of the plastic piping revealed it to be as good as new.

Use of Crane plastic piping expanding

Made of nontoxic virgin resins, Crane plastic pipe and fittings now are used to carry more than 30 chemicals and products such as beer and other beverages, acids, salt solutions, and alkalies.

Crane plastic piping is lightweight, can be easily installed by one man using simple tools, saves manhours and is not affected by freezing. It is available in standard wall and pressure-rated pipe, with working pressures up to 100 psi at 75° F.

Ask your Crane representative for a new booklet describing Crane plastic pipe and fittings.

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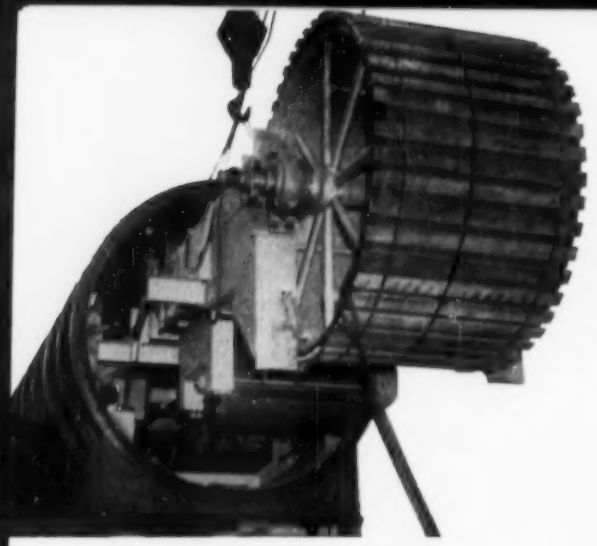


Fig. 3. Installing conveyor in chamber.

Continuous vacuum dehydration reduces costs

How does a continuous vacuum dryer operate? What are its principle fields of application? What are its main advantages over batch drying methods? What are the factors to be considered in the design and specification of this type of equipment? Here is an authoritative report which summarizes the results of 12 years of development work by the Chain Belt Co.

Fred Fixari, Weld Conley, and G. K. Viall

Chain Belt Company, Milwaukee, Wisconsin

The art of vacuum dehydration, the advantages of using low temperature, and the general superiority of products obtained by these techniques is well understood. However, up to the present, there have been serious technical obstacles to the continuous vacuum dehydration of certain heat and oxidation-sensitive or thermoplastic food products, chemicals, and pharmaceuticals.

During World War II, a need for low cost drying equipment for blood plasma and antibiotics stimulated intensive work in this direction on the part of the Chain Belt Co. While the work was not completed in time for this machine to play a wartime role, development was continued until, at the present time, the technique is considered ready for large-scale commercial application.

Present applications include soluble coffee, citrus bioflavonoid compound, and orange and grapefruit crystals. Promising products still in the laboratory or pilot plant stage are dehydrated tomato paste or juice, dehydrated whole milk, food supplements, and several chemical and pharmaceutical products.

For economic reasons, materials to be dried are generally in the form of heavy concentrates, although dilute solutions of many products may be handled satisfactorily. Such concentrations range from a low of 15 or 20 per cent solids to a high of 75 per cent.

Advantages claimed for this method include:

1. Lower cost than batch drying.
2. Relatively low drying temperatures.
3. Drying in the substantial absence of oxygen.
4. Ability to cool the product in vacuo immediately after drying.
5. Short drying time.
6. Improved cold water solubility.
7. Absence of heat damage.

Operating Principles

The feed material is introduced into the vacuum chamber at a predetermined temperature by means of a suitable metering pump. Within the chamber the material is applied evenly to the surface of a stainless steel belt, which serves as an endless conveyor to carry the product through several heating zones, and finally through a cooling zone. After cooling, the dry material is doctored from the conveyor belt and subsequently removed from the vacuum chamber through suitable pressure locks.

Equipment Details

Figure 1 is a schematic drawing of a typical vacuum dryer built by the Chain Belt Co. After introduction into the vacuum chamber the liquid product is applied to the underside of the stainless steel belt by means of a roller applicator. On the opposite side of the belt is a roller or pulley which insures that the belt will be flat at the point of application and that a predetermined clearance can be maintained between the feed roller and belt. This clearance may be varied from a few

(*Continued on page 112*)

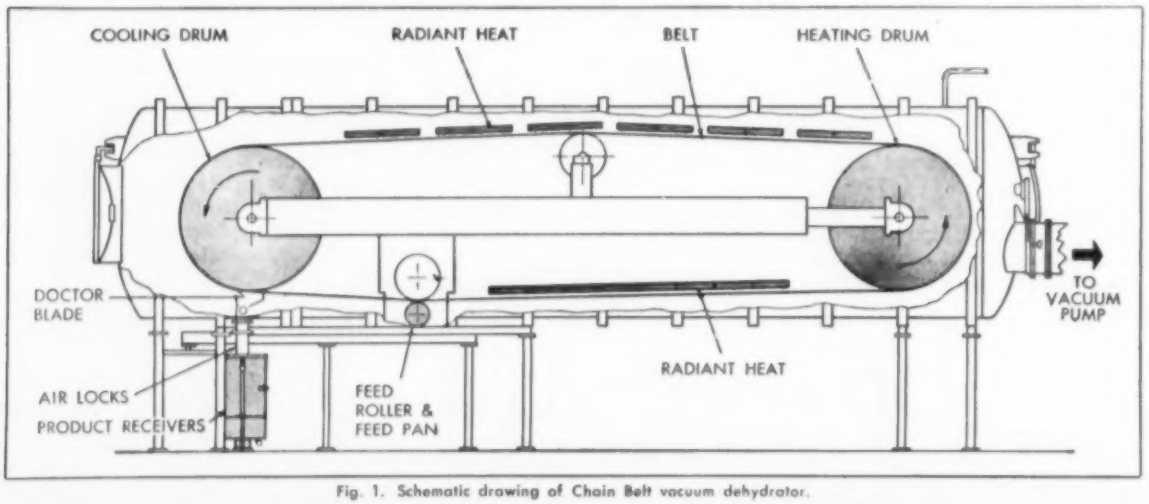
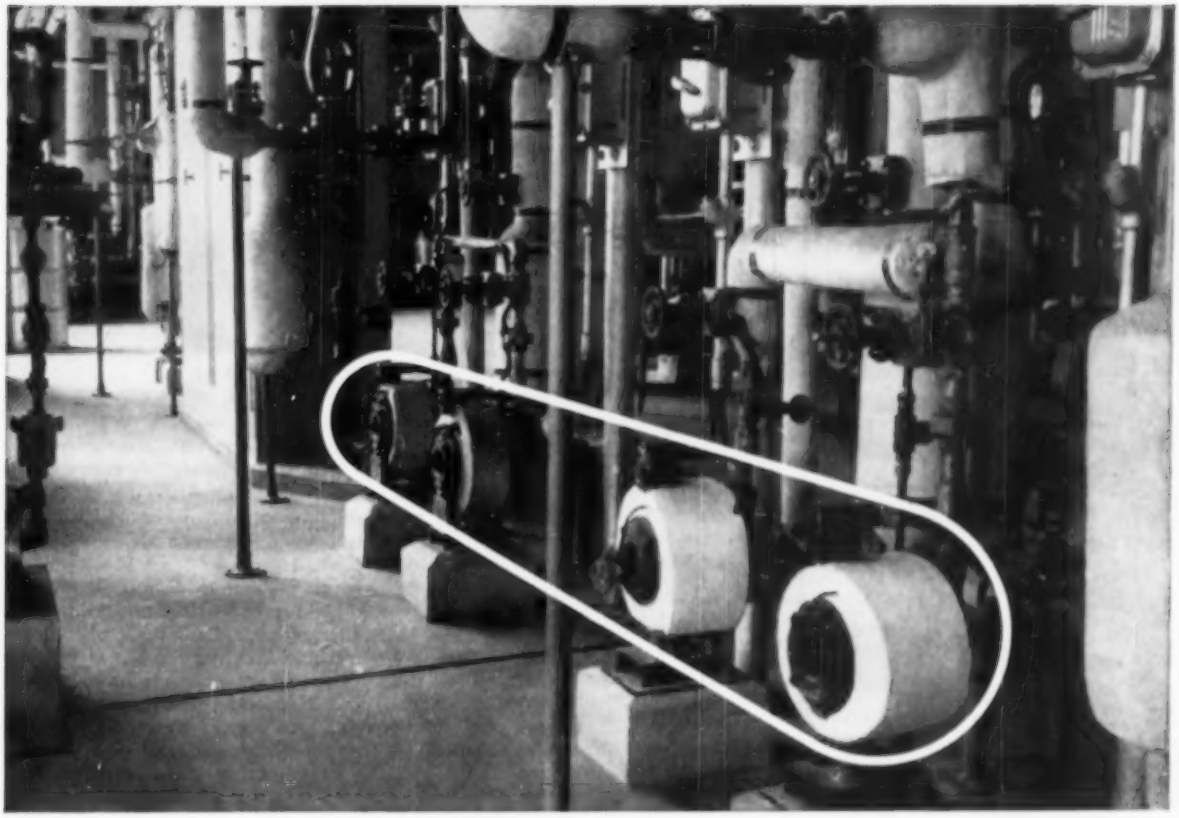


Fig. 1. Schematic drawing of Chain Belt vacuum dehydrator.



Chempump guards product purity

handling fine chemicals at Newport Industries plant

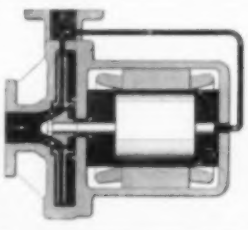
Forty-five *Chempumps* help keep product quality high and maintenance costs low at Newport Industries' new Fine Chemicals Plant at Pensacola, Florida.

These canned pumps handle synthetic U.S.P. Menthol, N.F. Thymol, U.S.P. Camphor, other high purity pharmaceuticals, and rubber chemicals. Leakage or contamination, which could be mighty costly in this application, are entirely eliminated. *Chempump* can't leak—in or out—because it has no seals, no stuffing box, no packing.

To further ensure absolute purity of products, pumps handling intermediates and final products are stainless steel. The pumps shown are steam traced and insulated to maintain required temperatures. All stators are protected with Class H high-temperature electrical insulation.

For Newport Industries, *Chempump* means completely closed-system fluid handling. What's more, the simplicity of *Chempump* design reduces maintenance to an occasional inspection and replacement of bearings. External lubrication is never required—bearings are constantly lubricated by the pumped fluid itself.

Why not profit by *Chempump's* many major advantages in your plant? For details, write to Chempump Corporation, 1500 Mermaid Lane, Philadelphia 18, Pa. Engineering representatives in over 50 principal cities in the United States and Canada.



Chempump combines pump and motor in a single leakproof unit. No shaft sealing device required.

U.L. approved. Available in a wide choice of materials and head-capacity ranges for handling fluids at temperatures to 1000F. and pressures to 5000 psi.

Chempump

First in the field...process proved

What's your Problem?

EVAPORATORS

FILTERS

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G-B, a leader in its field for over 50 years, offers complete responsibility . . . from design to finished product. Regardless of your processing problems, G-B has the practical experience, the engineering know-how and the manufacturing facilities to solve them. G-B Engineers are at your service at any time to discuss your processing problems . . . without cost or obligation.

Write for complete catalog showing the facilities and services of Goslin-Birmingham

GB GOSLIN-BIRMINGHAM MANUFACTURING CO., INC.
BIRMINGHAM • ALABAMA

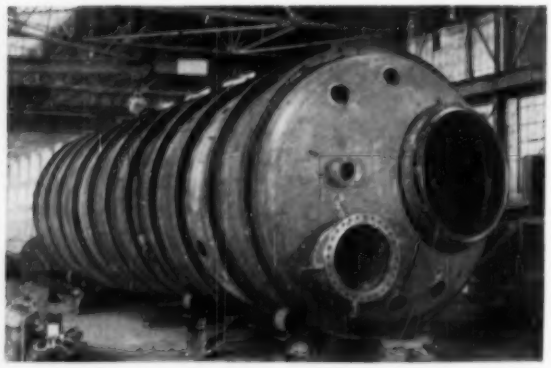

Fig. 2. Vacuum chamber in the process of fabrication.

CONTINUOUS VACUUM DEHYDRATION

(*Continued from page* 110)

thousandths of an inch to 20 or 30 thousandths, depending upon the characteristics of the material being dried and the desired layer thickness on the belt.

Situated above the belt and directly to the right of the feed section is a series of electrically energized radiant heating units with individual voltage controls so that the heat input can be profiled to the needs of the product. Since these heaters are on the back side of the belt, the heat flow is from the heater to the belt, through the belt and to the product. Radiant heaters on the lower or product side have also been found desirable for the drying of some materials.

After passing the first radiant heat zone, the belt passes around a steam jacketed heating drum. The temperature in this drum can be controlled to any desired level, but for practical considerations the usual range is between 140 and 300° F.

Following the heating drum the product is exposed to a second series of radiant heating units. At this point the radiant units are on the product side and heat is transferred directly from the radiators to the product. These radiant units also have individual voltage controls.

After the product is dry, the belt passes around a cooling drum. Thermo-plastic materials are solidified or crystallized. After the product is suitably cooled it is removed from the belt by a doctor blade. From this point it drops into a screw conveyor which is used to deposit it into one of two product receivers which are alternately filled and removed from the machine. When a receiver is full it is valved off, and the vacuum in the receiver is broken with an inert and dry gas. An empty receiver, upon being reconnected to the system, is evacuated with a separate pump before the lock to the vacuum chamber is reopened.

The drying cycle from point of application to removal from the belt is relatively short and with different products will range from 15 seconds to a few minutes.

The belt on the machine illustrated is 4 ft. wide and approximately 23 thousandths of an inch thick. It is a continuous ribbon of stainless steel made endless by butt welding the two ends of a strip. The large drums are 7¾ ft. in diameter, and the center to center spacing is 35 ft. The vacuum chamber is 12 ft. in diameter over the stiffening rings and approximately 52 ft. long.

Vacuum is usually maintained by a multi-stage steam ejector system.

(*Continued on page* 115)

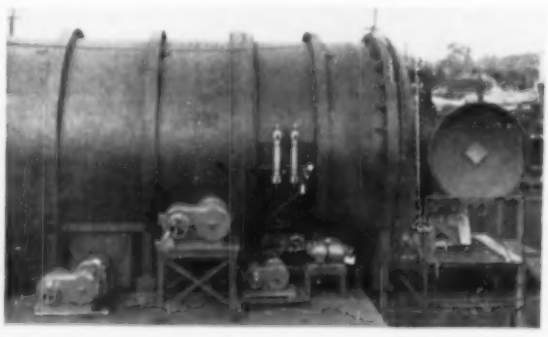

Fig. 4. Variable speed drive platform, showing (from left to right) feed roll drive, conveyor belt drive, dry product screw conveyor drive, and doctor blade oscillator drive.

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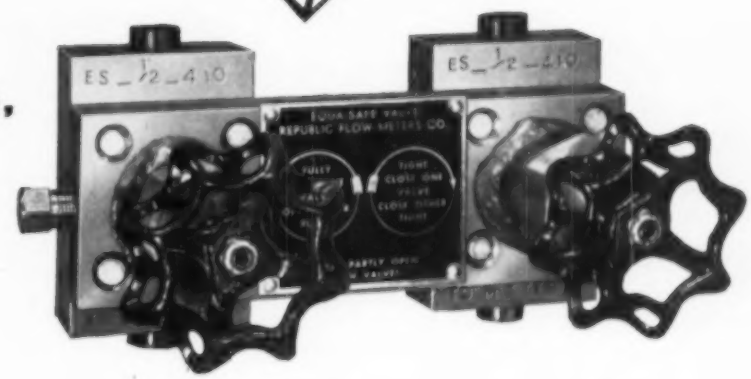
Valve Manifolds that STOP Mercury Blowing, Damage to Differential Bellows and Diaphragms



- CANNOT throw full line pressure across bellows, mercury or diaphragms of ΔP instruments.
- Replaces 3 or 4 conventional shut-off valves, fittings, etc.
- Rated to 4000 psi (cold)
- Available with angle, 3-way or through-type bodies threaded or socket- welded connections.

No conventional built-up valve manifold affords the protection EQUA-SAFE *automatically* gives to differential pressure type instruments. And no built-up valve manifold can beat the low installation time or low maintenance required by EQUA-SAFE valves.

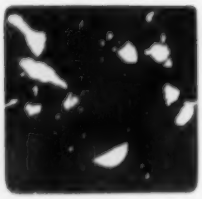
The "secret" of EQUA-SAFE's protection is in the common bridge-type bonnet and the two double-seating valves it connects. *When either valve is operated* (and sequence does not matter) *pressures in the two chambers of the differential instrument are automatically equalized through the bonnet.* As soon as both valves are fully "opened" (stem out) the instrument is on the line, with no leakage between sides. When both stems are in, the instrument chambers are interconnected and completely sealed off from primary connection pressures. Teflon packings are under pressure only while the stems are traveling from "seat" to "backseat", or vice versa!

Standard EQUA-SAFE valve manifolds are made of carbon and/or stainless steel, depending on your requirements. If your requirements are unusually severe, remember that EQUA-SAFE valves can be made of *any bar stock material that can be machined and welded!* When inspection or maintenance are needed, this bolted-block construction pays off again. EQUA-SAFE valves can be completely dismantled without breaking any pipe connections, and the inlet seat can be dressed up in place. A reversible backseat ring gives double wear, and is merely turned upside down to present a brand new seat.

Get the entire story on what EQUA-SAFE valves can do for your differential instrument installations. Write for Republic Bulletin No. 56-1, or ask your Republic engineer. Now that there is a top-quality instrument valve manifold for ΔP instuments, you should definitely investigate its applications in your plant.

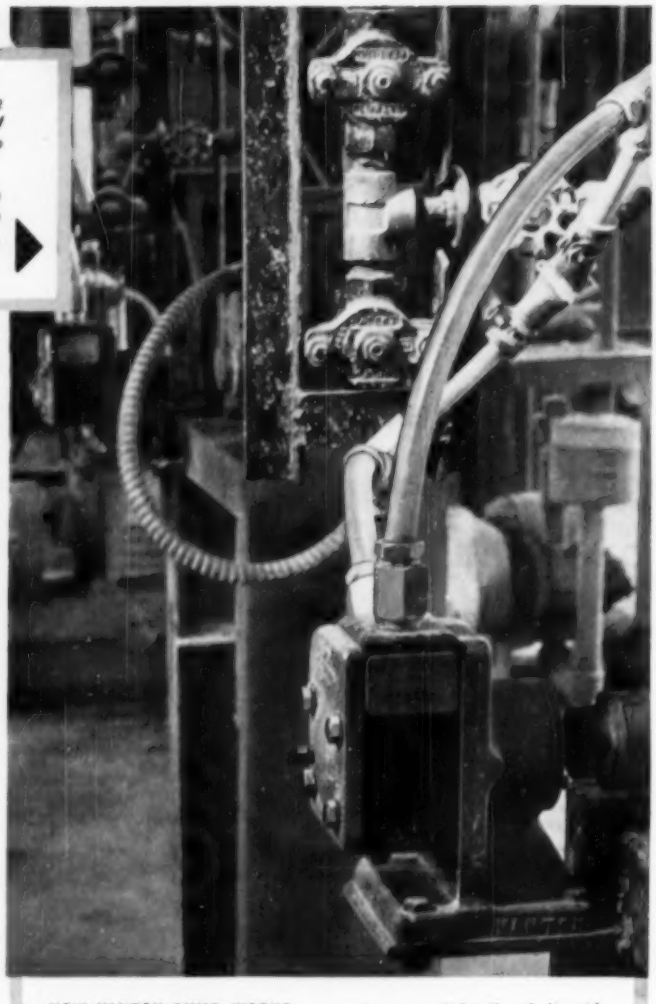
REPUBLIC FLOW METERS CO.

2240 Diversey Parkway, Chicago 47, Illinois



Highly abrasive: *ZrO_2 grains, X2150, are passed through the pump with no harm to internal parts.*

Vanton Sealless Pumps *Move 30% ZrO_2 Slurry From Settling Cones To Filters. Temperature 80-135°F.*



VANTON PLASTIC PUMPS (No Stuffing Box or Shaft Seals) Handle Acidic Abrasive 30% ZrO_2 Slurry With No Leakage

At Zirconium Corp. of America's Solon, Ohio Plant

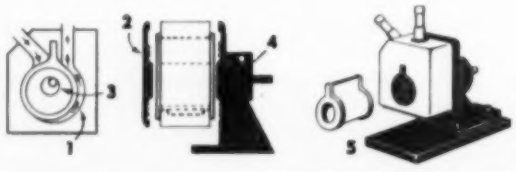
Pumping zirconium oxide (ZrO_2) slurry is no easy job. At Zircoa's plant, where stabilized ZrO_2 is manufactured in a patented continuous-flow process, slurry must be pumped continuously. Before Vanton came on the job, these abrasive, acid slurries caused periodic breakdown of conventional pumps, eroding impellers, scoring shafts, causing packing leakage and corrosion.

When Zircoa shifted to Vanton sealless plastic pumps, which have no shaft seals or packing glands (see diagrams) these troubles ceased. The Vanton plastic body block and synthetic rubber flex-i-liner proved completely impervious to the acid slurry. The resilient flex-i-liner absorbs the abrasive effect of the slurry with minimal wear. With corrosion and abrasion eliminated, maintenance was reduced to the simple, infrequent replacement of the inexpensive flex-i-liner.

Whether your problem is corrosion, abrasion, or contamination, you will find a Vanton flex-i-liner pump right for the job. *Why not send for the complete story today?*

CHECK THESE VANTON SEALLESS PUMP ADVANTAGES! ● ***No stuffing box or mechanical seal to leak, contaminate, or require maintenance*** ● ***Self priming; high vacuum*** ● ***A full-time production tool*** ● ***Broad capacity range, ⅓-40 GPM*** ● ***Available in 7 body and 10 flex-i-liner materials, to handle a wide variety of corrosives and abrasives.***

HOW VANTON PUMP WORKS • Liquid flows in channel between molded plastic body and synthetic flex-i-liner (*1*). No liquid touches metal. Liner flanges secured to plastic body block by bolted face plates (*2*). • Pumping mechanism is rotor mounted on eccentric shaft (*3*). At each revolution it pushes liner against body block and sweeps a "slug" of liquid around the circular track from inlet to outlet. • All bearings are outside of fluid area and located within protective stainless steel assembly in the event of flex-i-liner failure (*4*). • Liners are replaced in minutes, with pump in place, by simply removing face bolts and face plate, slipping old liner out, new one in (*5*).



SEND COUPON FOR FACTS!

Vanton Pump & Eqpt. Corp., Hillside, N. J. Dept. **CEP-3**

My pumping problem is .....

NAME .....

TITLE .....

COMPANY .....

ADDRESS .....

CITY ..... **STATE** .....

VANTON PUMP
and Equipment Corp. • Hillside, N. J.
DIVISION OF COOPER ALLOY CORP.

CONTINUOUS VACUUM DEHYDRATION

(*Continued from page* 112)

Usual drying pressures range from 500 microns to 10 mm. Hg. abs. However, most products are dried at from 1 to 6 mm. Hg. abs.

Fabrication Procedure

Figure 2 shows a vacuum chamber in the process of fabrication. At the near end is a 5½-ft. diameter access door and a 30-in. flanged fitting for connecting the vacuum system. The next step in the assembly is to install the conveyor system in the vacuum chamber. This operation is shown in Figure 3.

The feed roller, conveyor, screw conveyor, and doctor blade oscillator are driven by variable speed drives. These drives are shown in Figure 4.

One of the drum hubs, a bearing, and a rotary joint are shown in Figure 5. The bearing is an anti-friction type suitable for use in vacuum and under extreme conditions of temperature. The rotary joint is used to pass coolant in or out of the drum, or for admitting steam or removing condensate.

Design Considerations

Determining design factors are drying pressure, type and temperature of heat source, rate of heat input, method and degree of cooling after drying, drying time, and product temperature during drying. Important conditions of the feed material include temperature, concentration, viscosity, adhesion, and gas content. The chemical composition and formulation of products are also of great importance.

The drying process is a function of three readily controllable variables. These are time, temperature, and pressure.

In many cases the drying pressure is used as a tool to promote rapid dehydration with little regard to the product temperature during drying. In the case of materials which are ex-

(*Continued on page* 116)

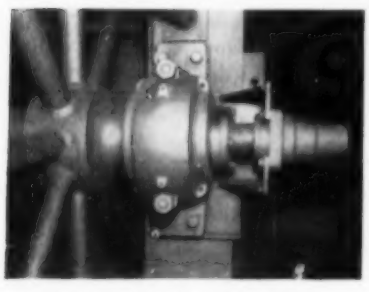


Fig. 5. Cooling drum hub, bearing, and rotary joint.

PAUL O. ABBÉ

Spiral Blade Mixer

GIVES SMOOTH, INTIMATE BLEND WITHOUT PILE-UP

NOTE—No piling of material at either end. Material is uniformly distributed by the blade while running. This mixer has inner and outer blades.

THIS Paul O. Abbé Mixer features a double spiral blade, with opposed blade pitches. Blade shape, pitch, and speed are accurately engineered to the characteristics of the materials to be mixed.

As the shaft rotates, both blades are mixing material. The moving blades pick up the particles of material, causing them to tumble over the edges of the blade and mix with other particles, imparting a folding, blending action. This also creates a gentle directional movement of the particles. As the outer spiral blades work the material from the end of the mixing chamber toward the discharge, the inner spirals work it back again, thus avoiding piling up.

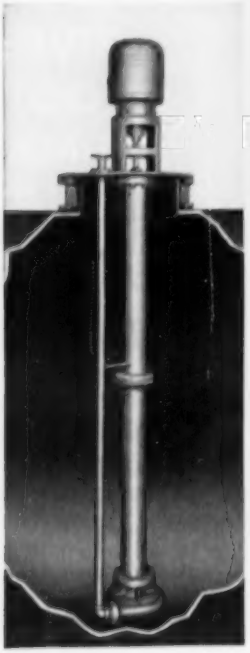
In addition to the mixing action applied by each blade, there is a further intermingling, blending action caused by the confluence of the inner and outer directional streams. An intimate, homogeneous mix is achieved and pile-up of material due to unidirectional flow is avoided.

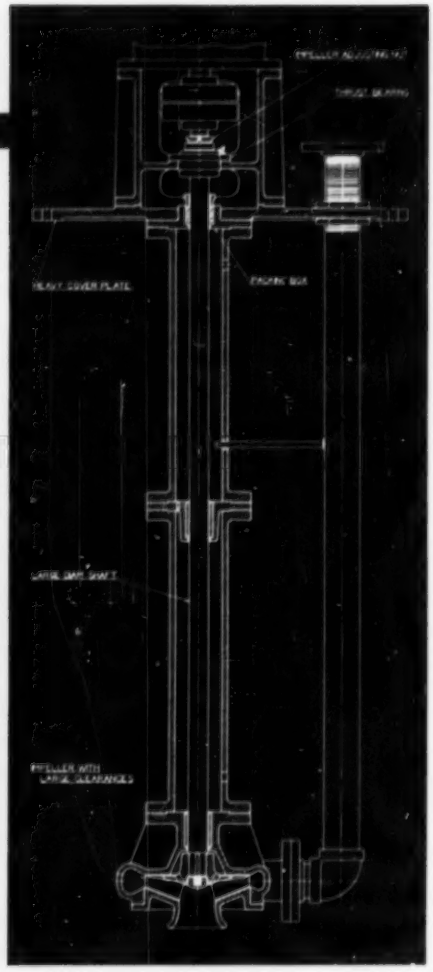
WRITE TODAY FOR MIXER CATALOG "V-1"

PAUL O. ABBÉ INC.

271 CENTER AVENUE LITTLE FALLS, NEW JERSEY

(Right) Structural details of Lawrence Vertical Chemical Pump.
(Below) Vertical Chemical Pump mounted inside of tank.



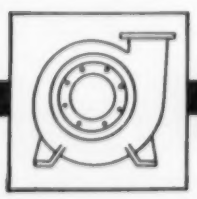


VERTICAL CHEMICAL PUMPS

Difficult chemical pumping problems—handling hot concentrated acids, corrosive alkalies, molten salts, molten sulphur, volatile semi-fluids, etc.—have been a LAWRENCE specialty for over 80 years.

To meet the demands of this rigorous service, LAWRENCE Vertical Chemical Pumps are made of metals or alloys carefully chosen to give the best protection against the corrosive and abrasive action of the liquid pumped, as well as structural strength and long wear. Other design features (depending on the circumstances) include liquid seals for high vacuum, the elimination of packing, mounting bearings above the level of the liquid pumped to prevent contact, and many more refinements that contribute vitally to efficient, trouble-free operation.

If you have a particularly difficult chemical pumping problem, write us the pertinent details.



LAWRENCE PUMPS INC.

371 MARKET STREET, LAWRENCE, MASS.

CONTINUOUS VACUUM DEHYDRATION

(*Continued from page* 115)

tremely heat sensitive, it is usually best to conduct the dehydration at pressures very near the equivalent freezing point temperature.

It is advantageous to use a product temperature as high as practical to attain a substantial pressure difference between the product vapor pressure and the operating pressure. If the material being processed is not particularly heat sensitive, a high product temperature may be used with a resulting high vapor pressure and consequently a high production rate. Feed material should be concentrated prior to drying for economic reasons. The best concentration may be a compromise based on economics, desired characteristics of the dry product, ease of drying, and maximum running time before cleaning is necessary. Too dilute a solution may drip or spatter from the belt or may fail to expand to give the desired structure. Too concentrated a solution may tend to "set up" in the feeding mechanism, necessitating frequent cleaning of the equipment, or may be difficult to apply to the belt.

Operating Phenomena

Immediately upon application to the belt most products tend to puff or expand. This phenomenon facilitates drying and contributes to the appearance and high solubility of products dried by this procedure. This expansion is accomplished through at least three simultaneous actions: 1) the action of the feed roll pulling away from the belt; 2) deaeration and evaporation; and 3) gravity. Puffing increases the vapor escape path and the surface area for heat transfer several hundredfold. The major portion of the expansion occurs upon application to the belt and during the initial stages of heating. This expansion is caused by a combination of degasification and the formation of small vapor bubbles within the mass. The residual heat in the belt after leaving the cooling drum supplies the required sensible and latent heat. Gravity assists in holding the mass in the puffed position while the preliminary conditioning is occurring.

Before passing over the heating drum many products are benefited by passing through a preconditioning radiant heating zone. Two things are thus accomplished: the product is preconcentrated until it has sufficient physical strength to support the ex-

(*Continued on page* 118)

Here's a crystal ball

that accurately predicts metal performance at high temperatures:

Inco's in-plant test rack program

Do you know that Inco sets up a test rack containing a large selection of alloys in critical hot spots in many types of operations: — one rack or more . . . whatever it takes to find out which alloy stands up best under a host of varying high temperature conditions.

What's more, Inco's High Temperature Engineering Service tabulates the data . . . analyzes it in a report like the one above: complete . . . accurate . . . unbiased.

Perhaps the answer to your high temperature problem has already been found . . . if not, we will be glad to arrange for a rack test. All you have to do to get the crystal ball rolling is to fill out the coupon below. Do it now.

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Please send me the High Temperature Work Sheet so that I may outline my problem to you.

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. . . for all fine filtering

SPARKLER HORIZONTAL PLATE FILTERS

Versatile adaptability makes this filter the logical choice of filtration engineers for difficult filtering problems.

Plate assembly is especially designed with positive seal to prevent trapping of air.

Every filtering job usually presents an individual problem involving a combination of various kinds of screens, papers and filter aid. Frequently temperatures are encountered that call for a brine or steam jacketed tank. Linings; plastic or rubber may be needed, with tank and plate metals to fit the product such as mild steel, monel, nickel, stainless steel, bronze or Hastelloy. Constructed to meet ASME specifications when required.

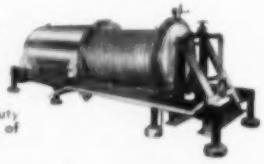
All these structural and material combinations are easily achieved with the Sparkler Horizontal Plate filter.

No fibrous adhesive material is ever required to hold the filter cake on the horizontal plate. The cake is firmly supported on the plate with no danger of cracking or slipping even with a variation in pressure or a complete shutdown in the filtering operation. The patented Sparkler scavenger plate filters almost the last drop in a batch, and allows practically a complete recovery of the product.

Constant filtering quality is maintained from start to the end of the cycle, no break through can occur in a Sparkler Horizontal Plate filter.

Place your filtering problem in the hands of our filtration engineers. They have developed many successful methods of filtering difficult materials and may be able to prescribe a solution to your problem without wasteful experimentation.

Write Eric Anderson



Model MCR heavy duty filter. Up to 1000 sq. ft. of plate area.

Model SCJ heavy duty water filter. Capacities up to 5,000,000 gal. per day.

SPARKLER

MANUFACTURING CO., Mundelein, Illinois

Sparkler International Ltd. with plants in Canada, Holland, Italy and Australia—Service representatives in principal cities throughout the world.

For over a quarter of a century, engineers and manufacturers of a complete line of industrial filtration equipment.

CONTINUOUS VACUUM DEHYDRATION

(*Continued from page* 116)

panded layer during subsequent drying, and the belt temperature is raised to approximately that of the heating drum. This reduces the shock of the extremely rapid evaporation which occurs on the drum. The radiant heat is first applied on the back side of the belt, and drying consequently occurs first next to the belt. This serves to produce a porous structure which affords an avenue of escape for vapor during the rapid evaporation occurring on the heating drum. If this first radiant heat zone is not used, a lower heating drum temperature must be employed with some products to limit boiling and possible spattering from the belt.

After leaving the heating drum, where approximately 80 to 90 per cent of the drying occurs, the material passes under the last zone of the radiant heat. In this zone two things are accomplished. The moisture is reduced to an acceptable level and the bulk weight is controlled. It is extremely important to maintain the expanded layer while accomplishing the first requirement. After the desired moisture level has been reached, the puff may be partially collapsed or reduced in size by further heating to that dictated by the final bulk density.

Cooling

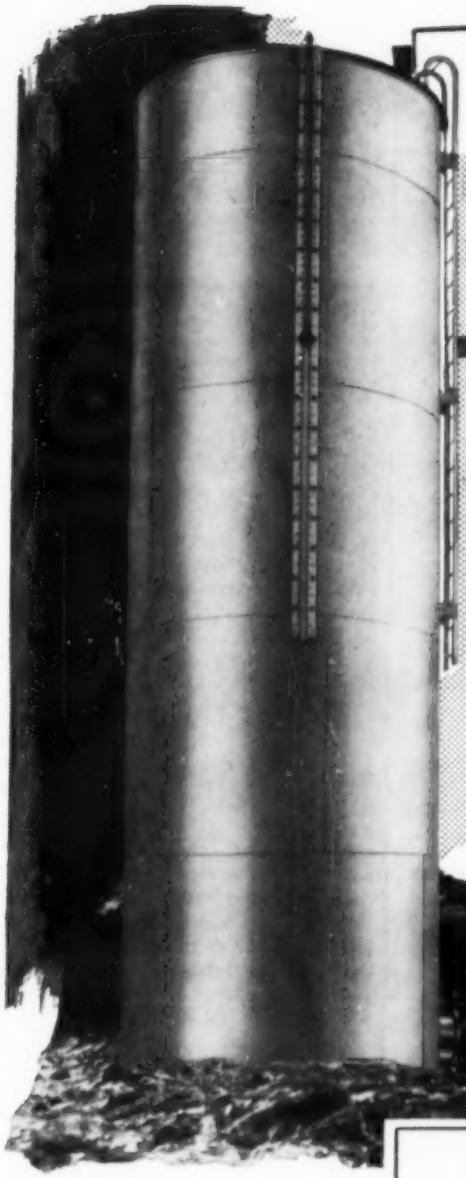
After drying is complete, most products are benefited by quick cooling. Thermo-plastic materials must be cooled well below the melting point prior to doctoring. Inadequate cooling will result in the production of an unsatisfactory product which may range from a taffy-like mass to a gummy sheet requiring subsequent cooling and grinding.

Oxidation-sensitive or flavor-labile materials should be thoroughly cooled in vacuo after drying. This eliminates the need for subsequent cooling steps in the presence of oxygen or the possibility of degradation by storage at elevated temperatures.

Cooling of the belt prior to the application of the product is in some cases a more rigid requirement than cooling of the product. A cool belt at the point of application takes on a heavier and more uniform layer of product and may contribute to the subsequent formation of a product structure favorable to rapid dehydration.

Further product applications and information can be had by circling number 398 on the Data Service Post Card, page 66.

76 years of KOVEN fabricating *Experience* built into every job



Acid Storage Tank Made of Stainless Clad Steel

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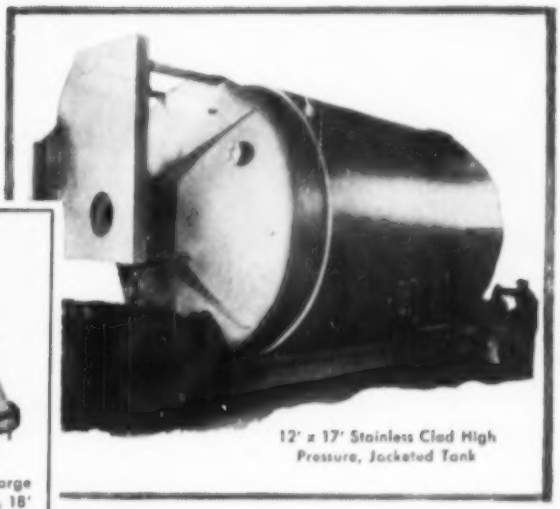
KOVEN equipment in all metals and alloys includes: High pressure vessels built to A.S.M.E., A.P.I. Codes; extractors; mixers; stills; kettles; tanks; stacks; breechings; hot transfer lines; large diameter fabricated piping and plate exhaust ducts; shop and field erected storage tanks; high vacuum testing.

SPECIALISTS IN INTRICATE FABRICATION USING:

STAINLESS STEEL • ALUMINUM • MONEL
NICKEL • INCONEL • ALL CLAD MATERIALS
NICKEL PLATED STEEL

Fabrication to all A.S.M.E. Codes



12' x 17' Stainless Clad High Pressure, Jacketed Tank

A.S.M.E. Steel Reducer 13' large diameter; 6' small diameter, 18' high, ⅝" steel throughout

80' Diameter Clarifying Tank—Field Erected

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"Kerodex"® spreads on easily and acts like a glove that is invisible yet strong and flexible. Does not smear. Does not affect materials handled nor is it affected by them. Available in two types. For full information write to Ayerst Laboratories, 22 East 40th Street, New York 16, N. Y. 5670

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This 21 foot, all carbon steel heat exchanger is protected against tube side to shell side leakage by double tube sheets at each end. In addition to the tubes being rolled into each tube sheet they are welded to the outside tube sheets for maximum strength and protection.

Units such as this by operating efficiently year after year, in a wide variety of applications, offer the strongest possible testimonials to Manning and Lewis "know how" in design, engineering and fabrication for the process industries.

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RESEARCH NEWS

Ground has been broken and construction started on Atlas Powder Co.'s $3 million Technical Center at Wilmington, Del. The Center is planned to enable the company to intensify its long-range basic research program as well as expand its technical service to the chemical industry. Extensive facilities will be available for work across the entire range of applications of its sorbitol, emulsifiers, detergents, polyester resins, activated carbons and explosives. Both design and construction are being carried out by H. K. Ferguson Co.

A new high-strength corrosion resistant cast alloy with better mechanical properties than "18-8" stainless steels has been developed by Ohio State University's Corrosion Research Laboratories as part of the research program of the Alloy Casting Institute. The alloy is designated as type CD-4MCu. □

The nuclear radiation or "hot" laboratory of Sinclair Research Laboratories, Inc., in Harvey, Ill., will provide facilities for two phases of atomic research: the effect of radiation from uranium reactor fuel elements on petroleum products and processes; and the use of radioactive tracers to determine the fundamental characteristics of these products and processes. Completion is scheduled for late February. □

A new Philips impulse generator of advanced design, first of its kind in the U. S., and rated at 1,400,000 volts with an energy of 16 kilowatt-seconds, went into service recently in the High Voltage Laboratory of Simplex Wire & Cable Co., Cambridge, Mass. The installation will play an important part in the company's expanding research and development program. □

A new pilot plant that turns out a ton or more of butyl rubber a day for experimental purposes has gone into service at Esso Standard's Baton Rouge, La., Research Labs. □

A new process for making tetraethyl lead has been discovered and is being developed by the research laboratories of Ethyl Corp. The chemistry of the new process involves a reaction between a metal alkyl and a lead compound. While still in the early stages, the process shows considerable promise. □

(Advertisement)

Corrosioneering News

Quick facts about the services and equipment available to help you reduce corrosion and processing costs.

Published by The Pfaudler Co., Rochester, N.Y., U.S.A.

Pilot Plant Spans Pharmaceutical Operations—Almost any operation in pharmaceutical manufacture can be performed in this new 4 x 9 x 2½-ft. pilot plant unit designed for Lakeside Laboratories, Milwaukee, by Pfaudler. It can reflux, react, distill and handle quickly a host of functions. High-vacuum distillation is done at as low as 50 microns Hg absolute pressure. All of the equipment is made of Type 316 stainless steel.

Unusual pilot plant assembly steps up Lakeside's synthetic work

"Virtually all pilot plant operations in pharmaceutical chemistry can be performed in a single new compact assembly specially designed for Lakeside Laboratories, Inc.," states Joseph N. Jacques, plant engineer.

The assembly, part of the expanding synthetic chemistry division, was made to Lakeside specifications by Pfaudler. It requires a floor space of only 4 feet by 9 feet by 30 inches.

It can reflux, react, distill and handle quickly a host of physical and chemical functions. The new unit is particularly noteworthy because high vacuum distillations are achieved at as low as 50 microns Hg absolute pressure.

Made entirely of Type 316 stainless steel, it will handle most of the organics used in Lakeside's products. It is presently used for distilling N-Ethyl-3-Hydroxypiperidine.

All of the initial synthetic work is concentrated on the production of antispasmodics, produced under the trade names of "Dactil," "Piptal," and "Cantil." The staff has found the equipment fast, versatile and easy to manipulate, Mr. Jacques said. The unit can be used for small-scale pilot plant operations as well as full-scale production.

Low-cost corrosion-resistant "Chemstors" widely used for storing organics and inorganic acids, polyvinyls, distilled and potable water, etc. Glassed steel prevents product contamination, is easy to clean. Sizes range from 750 to 35,000 gallons (above). Horizontal or vertical construction.

Test glassed steel dryer-blender obtains amazing results for users

On test at one of the leading pharmaceutical companies recently, the new Pfaudler glassed steel dryer-blender (patents applied for) came through with flying colors on several products.

The most difficult test, done first, involved a material that had the consistency of whipped cream. The results were amazing, and *proved that one Pfaudler unit could be used to dry seven to ten different products, replacing three conventional tray dryers of 100 trays each!*

Results like these speak for themselves and in this instance the manufacturer placed an order for a 6-ft. Pfaudler dryer-blender on the spot. You are invited to test your products in our laboratory test blender, sending your own men along to observe results, if desired. Or, we can arrange to send a field unit to your plant.

One of the biggest built so far—255 cu. ft. Fully charged this blender weighs 20,000 lbs. Heavy-duty gear drive tumbles bucket at 8 RPM with 15 HP motor. Magnetic brake gives instant and positive control.

THE PFAUDLER CO.
Dept. CEP-3, Rochester 3, N.Y.

Please send me the following:

☐ Chemstor Tanks, Bulletin 918;

☐ Dryer-Blender Data Sheet 26.

Name .....

Title .....

Company .....

Address .....

City ..... Zone ..... State .....

Two reports from the Boston Annual Meeting

Do you want to
OWN YOUR OWN BUSINESS?

Would you be willing to undertake
- **five to ten years of skimpy living,**
- **day and night work,**
- **very little time with your family;**

if you could have
- **freedom of action,**
- **the right to organize your own work,**
- **financial security?**

Why do men wish to run their own show? What are the advantages and disadvantages of owning your own business? What are the personal qualifications and characteristics necessary for success? What are the chances for success today?—These questions and related problems were attacked at the December Boston National Meeting of A.I.Ch.E. by a panel of outstanding industrial leaders.*

* W. L. Abramowitz, The Borden Company, New York, N. Y.; W. I. Burt, Goodrich Gulf Chemical Company, Inc., Cleveland, Ohio; G. F. Doriot, American Research and Development Corporation, Boston, Mass.; C. L. Knowles, Knowles Associates, New York, N. Y.; and G. G. Brown, University of Michigan, Ann Arbor, Mich. (moderator).

Freedom for a man to translate ideas into action with only himself as a buffer—this, according to Abramowitz of Borden, is perhaps the strongest incentive which drives men into private business ventures. Combined with this freedom to take risks and to bear the consequences is the lure of more money than can usually be gained by working for someone else. The final goal of such a course is the accumulation of money via capital gain—a goal which can be reached only rarely by a man working for a fixed monthly or yearly salary.

It was pointed out by Georges Doriot, of American Research and Development, that psychological factors, some conscious and others subconscious, often enter deeply into such a decision. For example, he said, students of good natural intelligence who do badly in school because of their innate unwillingness to accept discipline are often possessed of exactly those qualities which make for success in one-man businesses. This point of view was seconded by W. L. Burt of Goodrich Gulf Chemical, who said that such choices cannot be forced; they must inevitably be left to the character and inclination of the individual.

The Price of Success

The freedoms and potential financial security inherent in owning your own business have their price, a price which many would consider exorbitant. The man who takes this road, said Abramowitz, must be prepared for five or ten years of skimpy living, day and night work, and very little time with his family. An entrepreneur, he said, must

(*Continued on page* 124)

What is a
CHEMICAL SALES ENGINEER?

In previous issues *CEP* has analyzed how you judge and compensate a chemical sales engineer, how you train him. But just what kind of man will make a good sales engineer—what must he have? Boston panel * agrees that he must be an engineer, a salesman, something of a psychologist.

A sales engineer must be an engineer. This is basic. As sales manager Edgerly put it, "the sales engineer develops markets by knowing the engineering involved, by knowing the plant and the processes of the company he is selling."

But, given the engineering training, (and it does not have to be in a college, Bristol's vice president Beane emphasized, "As a general rule, men who have graduated from strong engineering colleges are the best choice, . . . there are, however, many men who have studied part time or by correspondence, or who have gained wide practical experience, and thereby have become equivalent to a graduate engineer.") it is the salesman, the personal characteristics of the sales engineer, that should dominate, according to the panel. "In a sales engineer the salesman half should dominate slightly over the engineer." (Beane) And, "the sales engineer must have the technical training, but his personal characteristics are probably more important." (Edgerly).

Expecting considerable debate on this point, Beane went on to explain, ". . . an engineer who is weak in his sales aptitudes is prone to spend too much time discussing unnecessary engineering details and not enough time in closing the sale." Perhaps the best sales engineer-candidate is the engineer who has gone on to post-graduate training in business administration or other commercial courses (as advocated by MIT's Brooks in a previous Boston report).

* Boston Annual Meeting, December 9-12, 1956. E. D. Kane, Cuno Eng. Corp., chmn.; W. S. Berg, Arthur D. Little, presiding; Stuart Edgerly, sales manager, Fenwal, Inc.; W. Alec Jordan, Chemical Data Co.; H. E. Beane, vice president, The Bristol Co.

Personal Characteristics

"The true sales engineer creates a need, uncovers a problem or need not brought to light before," Edgerly insisted. The good sales engineer cannot sit back and let nature take its course, he has to try to stimulate business activity himself. For this, Edgerly explained, he must be able to plan his own work and stick to a program, he must be able to communicate readily, he must solve the technical problems his clients raise, and he must be flexible enough to deal with many different social backgrounds.

Beane puts the personal requirements another way. He sees the sales engineer as, first, self-sufficient. The man who needs supervision will not make a good sales engineer, nor will the man who likes to work in a more-or-less large team. On the other hand he must be cooperative. In fact, because he works mainly alone, he must be readily and efficiently cooperative with his supervisors and co-workers who are usually widely scattered. The "lone-wolf" is of little more value as

(*Continued on page* 125)

HOW TO SELECT WATER-CONDITIONING EQUIPMENT (NO. 1 OF A SERIES)

Aerators, Degasifiers, Deaerators

If you want to remove dissolved gases or iron or taste and odor from large quantities of water, you will probably use aeration or degasification as part of the treatment.

Modern equipment for putting air or gases into water or taking them out is highly specialized, ranging from simple, low cost aerators to complex, highly efficient degasifiers.

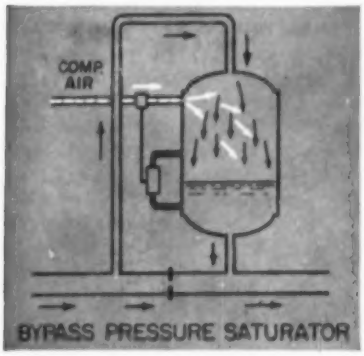
The following descriptions may help you choose the type of equipment that best solves your problem at the lowest cost.

To introduce air

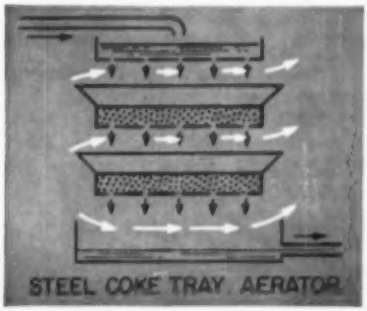
If your problem is simple introduction of air to oxidize iron or manganese, **pressure aeration** may be preferred to avoid repumping. But introducing air into water under pressure can result in supersaturation when the pressure is reduced, causing "milky water" and filter troubles from air binding or upset beds.

A Bypass Pressure Saturator automatically provides aeration without the danger of supersaturation by introducing air to only a predetermined portion of the total flow. (Patented by Permutit.)

If you want to reduce CO_2 or taste and odor or accomplish any of these at the same time that you oxidize iron or manganese, an **aerator** is recommended.

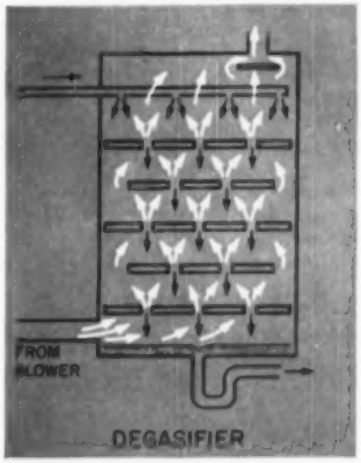


Aerators may be of the open type in which water cascades over trays of graded coke or a series of wood slat trays. Splash aprons reduce splashing, permit free circulation of air. Formation of iron or manganese film on coke surfaces hastens oxidation reactions. Some reduction of CO_2 may also take place, raising pH and further helping oxidation.



To remove dissolved gases

For practically complete removal of CO_2, methane, hydrogen sulfide or other gases, the most efficient way is by a **degasifier.**



In a degasifier, water rains down through Raschig rings or wood slat packing countercurrent to a large flow of air from a blower. Thus the freshest air contacts the effluent water, gives lower final gas content. Proper packing design breaks water into thin films, promotes rapid and efficient gas removal.

Degasifiers are totally enclosed, avoiding splashing and spray losses. Outer tank may be of wood, rubber-lined steel, stainless steel or aluminum. Cylindrical units are usually more economical, but square or rectangular shapes may be used. Sizes and capacities are practically unlimited, depending on requirements. Units can be used for water with CO_2 as high as 3500 ppm.

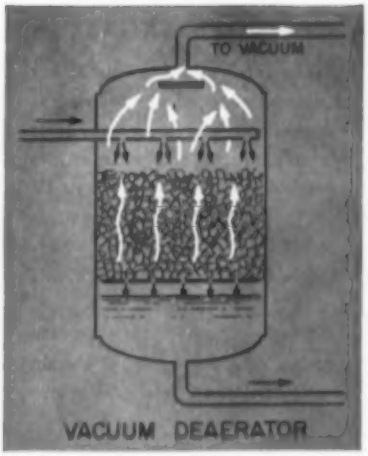
Although degasifiers provide very complete aeration, their higher cost is unwarranted in many cases where simple introduction of air is the main objective.

To remove oxygen

If you want to remove oxygen without heating the water, use **vacuum deaeration.**

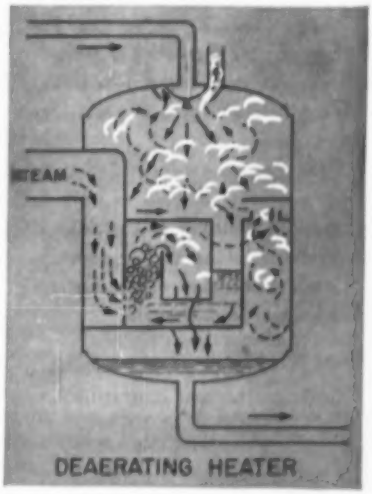
A vacuum deaerator is a steel tank lined where necessary and containing suitable packing such as Raschig rings. A vacuum is maintained in the tank by steam jet ejectors or motor-driven vacuum pumps. Under a vacuum, solubility of gases in water is greatly lowered. As the water trickles down through the packing, the gases present, including oxygen, nitrogen and carbon dioxide, are liberated and drawn off. Type and depth of packing, degree of vacuum, flow rates and other variables must be accurately adapted to your specific conditions for best efficiency.

If the water is to be heated as for feeding boilers, a vacuum is not necessary, and a **deaerating heater** is recommended.



In a spray type deaerating heater, the water is first sprayed through steam which removes most of the non-condensable gases. (The gas-laden steam is condensed and vented.) The water is then reboiled by passing steam through it for final deaeration.

Where less complete removal of oxygen is required, the reboiling (scrubbing) stage may be omitted.



For detailed information on these or any other types of water-conditioning equipment, write: The Permutit Company, Dept. CEP2, 330 West 42nd St., New York 36, N.Y. or Permutit Company of Canada, Ltd., Toronto 1, Ont.

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PIONEERS IN PROPELLANTS

The Jet Propulsion Laboratory has been engaged in the development of solid and liquid propellants for use in rocket and guided missile propulsion systems for the past 17 years. Pioneering achievements in both these fields have led to important contributions to the nation's guided missile program.

The propellant field offers a wide variety of problems to the chemist and chemical engineer. The search for new propellants, the stabilization and synthesis of high energy materials and the control of physical properties and combustion demand talents in physical, organic, inorganic and analytical chemistry. Special emphasis is placed on combustion, polymers, synthesis, free radical studies and kinetics.

The chemical engineer, at JPL, finds an unusually broad scope for applying his knowledge of thermodynamics, heat and mass transfer, fluid flow and general processing techniques.

If you are interested, a U. S. citizen, and qualified to work in these fields at this well established center of research and development, send your resume now for immediate consideration.

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A CENTER OF GUIDED MISSILE RESEARCH AND DEVELOPMENT

YOUR OWN BUSINESS

(*Continued from page 122*)

necessarily perform many of the functions ordinarily carried out by several members of the staff in a large company.

Compensations Can Be Many

The other side of the medal was described by Chester Knowles, of Knowles Associates, who painted a glowing picture of the advantages of the small organization. Freedom of action, the right to organize your work as you see fit, and financial security can be the fruits of a successful small enterprise, he said. A note of caution was interjected by Doriot, who warned that "you can't run a locomotive with a committee nor yet a small business." In other words, in any partnership or small business organized on a more or less personal basis, it should be made clear at the start who is the boss. Otherwise, said Doriot, misunderstandings and personal animosities are sure to have a negative effect on the enterprise as a whole.

Qualifications Are Varied

Some of the characteristics required of any man who aspires to found his own business were outlined by Abramowitz:

1. Experience—preferably three to five years in industry.
2. Vision to evaluate future needs.
3. A well-developed sense of the opportune.
4. Willingness to run risks.
5. Capital (but not necessarily too much).
6. Willingness to work 16 hours a day for seven days a week.
7. Ability to judge people instinctively.
8. Ability to make up one's mind and to act quickly.
9. Ability to do many things reasonably well instead of one thing very well.

Success Not Automatic

Because of the greater maturity of the chemical industry, the chances for building a small chemical company seem more remote than they were fifteen or twenty years ago. The tremendous capital requirements for plants to manufacture heavy chemicals or petrochemicals would seem to rule out this possibility for individuals or small partnerships. Opportunities today seem rather to favor the intermediate fabrication of products for the applications and consumer industries. Examples mentioned were adhesives, textile finishes, leather finishes, protective coatings, and the injection, compression, extrusion, and vacuum forming of plastics.

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ENGELHARD INDUSTRIES

Educational Field Offers Independence

According to George Brown of the University of Michigan, moderator of the panel, many men who crave freedom of action and of thought, and who would be unhappy working in a large company, can find satisfaction in the academic world as well as in small business. Such a situation, in the ideal case, can very well combine intellectual freedom with a high degree of financial security. This solution, said Brown, can be particularly advantageous for the engineer, since he can often supplement his academic salary with outside industrial consulting activities. The danger here, he added, is that a consultant may well end up with ten or twelve bosses instead of one.

CHEMICAL SALES ENGINEER

(*Continued from page* 122)

a sales engineer than the man who must be prodded to do his best. Self control is vital (sales engineering can be a discouraging job over the short term, requires sustained effort, often with slow results), as is aggressiveness. An unaggressive salesman is a contradiction in terms, but the day of the back-slapping drummer has also gone. Aggressive, yes, but not overbearing.

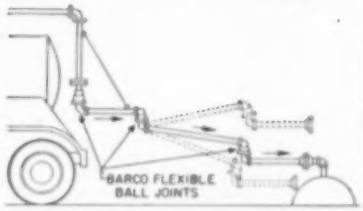
Psychology

There is a truism in the sales field that says, in effect, a good salesman is a born psychologist. Lost orders are more often than not psychologically caused. W. Alec Jordan, longtime sales engineer and former editor, pinpointed an often overlooked fact—all sales are made by words. People, even engineers, are *persuaded* to buy. The sales engineer must have a good deal of the psychologist in him. Engineers, Jordan said, are far from being as logical, accurate and scientific in their buying as they think they are, or as is assumed, and the good sales engineer will learn to study and recognize the more intangible factors involved in any selling effort. People, even engineers, Jordan emphasized, rarely know exactly the real reason they buy something. They buy because they *need*, but more important because they *want*.

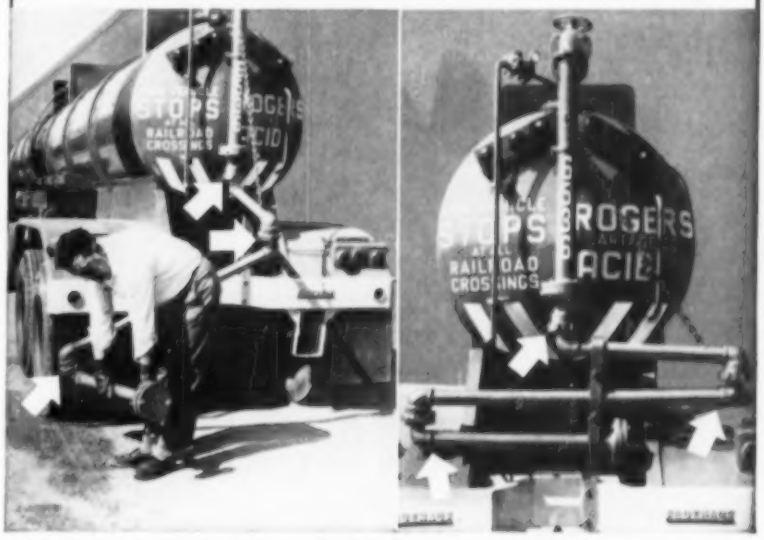
Conclusion

A chemical sales engineer must have good, thorough formal training, he must learn by actual selling. He must be judged, some yardstick found to measure his work. But he must also be an engineer of a temperament and interest to do the job. It is a big and growing field, and engineers with a flare for sales are badly needed.

For SAFETY and Lower Costs in Handling Sulfuric Acid



The accompanying sketch shows how three Barco Ball Joints in unloading (or loading) line provide complete flexibility for making connections in any position. Note how line folds neatly on back of truck when not in use (photo below).



Barco Flexible Ball Joints Replace Hose

Two near-accidents with hose blowing out some time ago, while handling sulfuric acid with 30 psi air pressure, caused Rogers Cartage Co. of Chicago to change to Barco Flexible Ball Joints (with malleable iron casing and stainless steel ball) in loading lines on some 15 big trucks serving many chemical, petroleum, steel, and other customers in the Midwest area. Since making the change, Mr. Jack Kidder, Rogers Safety Manager reports that there have been no failures and little or no maintenance on the joints. Cost for frequent hose replacement has been eliminated. *Inquiries are invited, address Barco. Ask for Catalog 215B.*

ADVANTAGES

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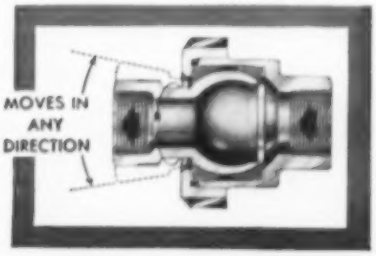

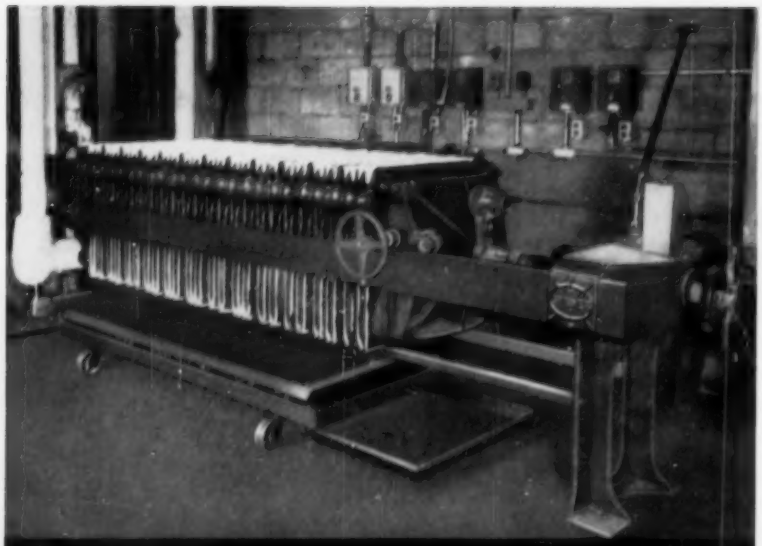

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FUTURE MEETINGS and Symposia of the Institute

View of Seattle from Queen Anne Hill, Mt. Rainier in background.

MEETINGS **SYMPOSIA**

■ **SEATTLE, WASH.**

June 9-12, 1957. Olympic Hotel.

TECHNICAL PROGRAM CHAIRMAN: James G. Knudsen, Dept. of Chem. Eng., Oregon State College, Corvallis, Oregon.

Industry's Role in University Programs on Nuclear Engineering

CHAIRMAN: John Kaufmann, Div. of Reactor Development, U. S. Atomic Energy Commission, Wash., D. C.

Chemical Engineering Data and Calculation Methods

CHAIRMAN: W. C. Edmister, Calif. Research Corp., Richmond Laboratory, Richmond, Cal.

Filtration

CHAIRMAN: F. M. Tiller, University of Houston, Houston 4, Texas.

Electrochemical Engineering

CHAIRMAN: Joseph Schulein, Dept. of Chem. Eng., Oregon State College, Corvallis, Oregon.

Chemical Engineering in the Pulp and Paper Industry

CHAIRMAN: J. L. McCarthy, Dept. of Chem. Eng., Univ. of Washington, Seattle, Washington.

Including: Economic Factors in the Design of Evaporators for the Pulp & Paper Industry; Corrosion and Equipment Design Relations in Magnesia-Base Sulfite Pulp Plant at Ketchikan, Alaska Plant; Pilot Plant Production of Dimethyl Sulfide; Chemical Engineering Trends in the Pulp & Paper Industry.

■ **EVANSTON, ILL.**

April 7-10, 1957. Northwestern University, Technological Inst. Auditorium.

Plant instrumentation symposium sponsored jointly by A.I.Ch.E. (Dave Boyd, Universal Oil Products Co., Des Plaines, Ill., chairman) and the Instruments & Regulators Div. of A.S.M.E. On the afternoon of April 9 there will be a session devoted to the dynamics of processes with Page Buckley, DuPont, presiding. Papers include: "Automatic Control in Continuous Distillation," T. J. Williams and R. T. Harnett; "Closer Control of Loops with Flow Times," O. J. M. Smith; and "The Stability of Some Chemical Systems Under Control," R. Aris and N. R. Amundson. Other sessions will be on application of automatic controls.

■ **ST. LOUIS**

June 2-6, 1957. Jefferson Hotel.

Golden Anniversary Meeting, Air Pollution Control Association; sponsoring societies include A.I.Ch.E. (Tuesday, June 4 will be A.I.Ch.E. day.)

Methods of Analysis; Instrumentation; Atmos

pheric Reactions, Photochemical & Other; Aerosol Formation & Control; Progress in Air Pollution Control Equipment & Methods; and Human & Economic Goals for Engineers in Air Pollution Control will be treated.

For information contact W. L. Faith, Managing Director, Air Pollution Foundation, 704 S. Spring St., Los Angeles 14, California.

■ **PASADENA, CALIF.**

June 19-21, 1957. California Institute of Technology.

The 1957 Heat Transfer and Fluid Mechanics Institute. A.I.Ch.E. is one of the sponsoring societies. Papers on technical and scientific advances in fluid mechanics, heat transfer, thermodynamics, and related fields.

GENERAL CHAIRMAN: Peter P. Wegener, Jet Propulsion Laboratory, Calif. Inst. of Tech., 4800 Oak Grove Drive, Pasadena 3, Calif.

■ **STATE COLLEGE, PA.**

August 11-14, 1957. Pennsylvania State University.

First National Conference on Heat Transfer featuring Applied Heat Transfer. Sponsors A.I.Ch.E., A.S.M.E., & College of Eng. & Arch. Penn State Univ.

James N. Addoms, Atlas Powder Co., Wilmington 2, Delaware, is A.I.Ch.E. program chairman.

■ **BALTIMORE, MD.**

September 15-18, 1957. Lord Baltimore Hotel

TECHNICAL PROGRAM CHAIRMAN: R. L. Copson, Mutual Chemical Co. of America, 1348 Block St., Baltimore 31, Maryland.

Adsorption, Dialysis, and Ion Exchange

CHAIRMAN: G. P. Monet, Du Pont, Wilmington, Delaware.

Intended to furnish basic information for chemical engineers working on mass separation problems.

Jet Propulsion

CHAIRMAN: C. E. Marsel, College of Eng., N.Y.U., University Heights, New York City 53.

The Alkali-Chlorine Industry

CHAIRMAN: Herman W. Zabel, Roger Williams, Inc., P. O. Box 426, Princeton, New Jersey.

Drying

CHAIRMAN: Ralph E. Peck, Chem. Engineering Dept., Ill. Inst. of Tech., Chicago 16, Ill.

Low Temperature Processing

CHAIRMAN: Clyde McKinley, Air Products, Inc., P. O. Box 538, Allentown, Pa.

Direct Operating Labor Costs

CHAIRMAN: John Happel, Chem. Eng. Dept., New York University, University Heights, N. Y. 53.

■ **ANNUAL—CHICAGO, ILL.**

December 8-11, 1957. Conrad Hilton Hotel.

TECHNICAL PROGRAM CHAIRMAN: Henry F. Nolting, Standard Oil Co., 2400 New York Ave., Whiting, Ind.

Fluidization of Solids

CHAIRMAN: E. R. Gilliland, Chem. Eng. Dept., M.I.T., 77 Massachusetts Ave., Cambridge 39, Mass.

Flow characteristics, rate of entrainment and heat transfer; fluidized reactors vs. fixed and moving bed reactors.

Effective Cost Control in Process Operations

CHAIRMAN: C. W. Nofsinger, The C. W.

(Continued on page 128)

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FUTURE MEETINGS

(Continued from page 127)

MEETINGS **SYMPOSIA**

Nofsinger Co., 906 Grand Ave., Kansas City 6, Mo.

Evaluation of Projects from the Original Idea to the Investment Stage

CHAIRMAN: C. W. Nofsinger (see above).

Chemical Engineering Abroad

CHAIRMAN: Shelby Miller, Chem. Eng. Dept., University of Rochester, River Campus Station. Rochester 20, N. Y.

Corrosion Resistant Alloy Materials of Construction

CHAIRMAN: G. Fred Ours, Carbide and Carbon, Charleston, W. Va.

Laboratory and Pilot Plant Techniques

CHAIRMAN: G. W. Blum, The Goodyear Tire & Rubber Co., 1485 E. Archwood Ave., Akron 16, Ohio.

Radiation Processing

CHAIRMAN: J. J. Martin, Dept. of Chem. Eng., Univ. of Michigan, Ann Arbor, Michigan.

Nuclear Process-Heat and Radiation Source Reactor Systems for the Chemical and Metallurgical Industries

CHAIRMAN: B. W. Gamson, Borg-Warner Corporation, Des Plaines, Illinois.

Extractive Metallurgy

CHAIRMAN: B. W. Gamson (see address above).

Selling a Technical Program

CHAIRMAN: W. L. Bulkley, Standard Oil Company (Ind.), Whiting, Indiana.

Shock-Wave Concept of Equipment Design

CHAIRMAN: Stuart Churchill, Dept. of Chem. Eng., Univ. of Michigan, Ann Arbor, Michigan.

Use of Computers in the Chemical Industry

CHAIRMAN: Leon Cooper, Monsanto Chemical Company, St. Louis, Missouri.

Biological Processes

CHAIRMAN: Elmer Gaden, Dept. of Chem. Eng., Columbia University, New York City.

Chemicals Recovery in the Paper Industry

CHAIRMAN: R. P. Whitney, Inst. of Paper Chemistry, Appleton, Wisconsin.

1958 MEETINGS

- Montreal, Canada, April 20-23, 1958. Sheraton-Royal Hotel. Joint A.I.Ch.E.-C.I.C. Conference. CHAIRMAN: H. R. L. Streight, DuPont Co. of Canada Ltd., P. O. Box 660, Montreal.
- Philadelphia, Pa., June 22-27, 1958. Bellevue-Stratford Hotel. A.I.Ch.E. Fiftieth Anniversary Meeting.
- August 18-21, 1958. A.I.Ch.E.-A.S.M.E. Heat Transfer Conference. CHAIRMAN: G. M. Brown, Dept. of Chem. Eng., Northwestern Tech. Inst., Evanston, Ill.
- Salt Lake City, Utah, September 21-24, 1958. CHAIRMAN: E. B. Christiansen, Dept. of Chem. Eng., Bldg., 437, Univ. of Utah, Salt Lake City.
- Cincinnati, Ohio, December 7-10, 1958. Netherland Plaza Hotel. A.I.Ch.E. Annual Meeting.

(Continued on next page)

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LOCAL SECTION MEETINGS

■ PHILADELPHIA-WILMINGTON

April 9, 1957. One-day meeting on "Catalysis in Practice" in conjunction with the University of Pennsylvania. Place: University Museum, Philadelphia.

AM: "Which Catalyst and Why?" A. Oblad, Houdry; "Preparing an Industrial Catalyst," F. G. Ciapetta, C. D. Helm, L. D. Barrel, Davison Chemical; "Fixed Bed Catalyst Systems," A. B. Stiles, Du Pont; "Moving Bed Catalyst Systems," J. M. Bourguet, S. J. Wantuck, Socony-Mobil.

PM: "Economics of Catalyst Use," R. M. Reitmaier, Girdler; "Operating Problems," J. M. Harris, Rohm & Haas; "Trends and Prospects," C. L. Thomas, Sun Oil.

Contact: L. R. Bechtel, Atlantic Refining Co., 2700 Passyunk Ave., Philadelphia 45, Pa.

■ AKRON—CINCINNATI—CLEVELAND—PITTSBURGH—TOLEDO

May 10, 1957. Joint one-day regional symposium on "Industrial Pollution Control," Sheraton-Mayflower Hotel, Akron, Ohio. Reservations and pre-registration: H. H. Baker, White Industrial Sales Co., 2nd National Bldg., Akron, Ohio. Cost: $1.00—student members; $2.00—A.I.Ch.E. members; $3.00—non members.

UNSCHEDULED SYMPOSIA

Correspondence on proposed papers is invited. Address communications to the Program Chairman listed with each symposium below.

- **Centrifugation:** James O. Maloney, Dept. of Chem. Eng., U. of Kansas, Lawrence, Kans. The theory and quantitative aspects of centrifugation.
- **Size Reduction:** Edgar L. Piret, Chem. Eng. Dept., U. of Minnesota, Minneapolis 14, Minn.
- **Filtration & Centrifugation:** Horace Hinds, Jr., Corn Products Refining Co., Box 345, Argo, Ill.
- **Chemical Engineering Process Dynamics as They Affect Automatic Control:** David M. Boyd, 315 Ridge Ave., Clarendon Hills, Ill.
- **Ethylene Manufacture:** Hermann C. Schutt, 201 Devonshire St., Boston 10, Mass.
- **Dry Classification of Solids:** D. W. Oakley, Metal & Thermit Corp., Carteret, N. J.
- **Saline Water Conversion:** W. L. Badger, 309 So. State Street, Ann Arbor, Michigan.
- **Statistics in Chemical Engineering:** John C. Whitwell, Princeton University, Princeton, N. J.
- **Education of Chemical Engineers:** F. M. Tiller, Dean of Eng., University of Houston, Cullen Blvd., Houston 4, Texas.
- **New Chemical Engineering Construction Techniques:** S. A. Guerrieri, The Lummus Co., 385 Madison Ave., N. Y. 17.
- **Mineral Process Engineering and Mineral Economics:** L. A. Roe, International Minerals & Chemical Corp., 20 North Wacker Drive, Chicago 6, Ill.
- **Foams and Froths:** J. L. York, Dept. of Chem. & Met. Eng., Univ. of Mich., Ann Arbor, Michigan.
- **The Threatened Imbalance Between Chlorine and Alkali in American Chemical Industry:** Zola G. Deutsch, Deutsch & Loonam, 70 E. 45th St., New York City 17.
- **Shock Waves in Process Equipment:** Chairman to be named.
- **Scale-Up Philosophy in the Chemical Industry:** Chairman to be named.
- **Start-Up of New Chemical Plants:** Chairman to be named.
- **Computers in Optimum Design of Process Equipment:** Chen-Jung Huang, Dept. of Chem. Eng., Univ. of Houston, Cullen Blvd., Houston 4, Texas.
- **Kinetics & Rate Processes:** Neal R. Amundson, Institute of Technology, University of Minnesota, Minneapolis 14, Minn.

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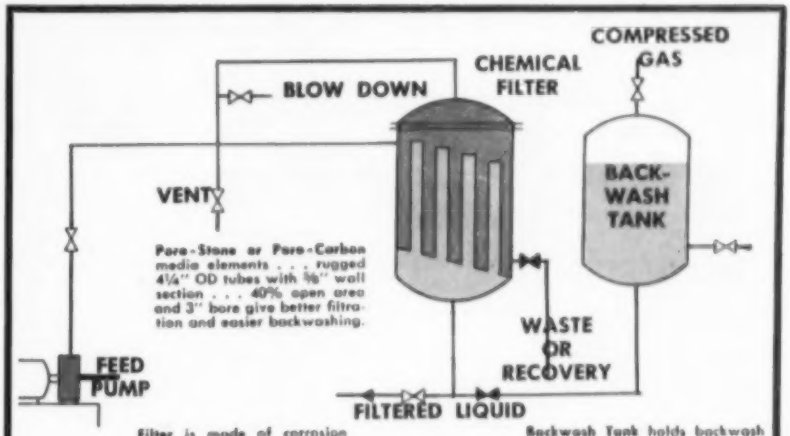
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Committee chairmen of the Twin City Local Section at the recent Minneapolis 1-day meeting: Mike Baker, Program vice-chmn.; Jack Zemlin, Program; Harvey Anderson, General; Dick Westeen, Registration; Jim Riggs, Arrangements; and Neil Amundson, Finance.

Discussed at recent Twin City one-day meeting were . . .

ORE IMPORTS, CHEMICAL PROCESSES, AND OUR MINERALS FUTURE

We are importing substantially larger portions of ores for commonly-used metals than ever before. This conserves our resources—but there is good reason to question just how rich many of these conserved ore-beds may be. And for meeting our needs a decade or two in the future, or defending ourselves in case of attack, better provision than importation should be made to assure enough supply to fill our needs for these metals. One route is the development of substitutes. Another entails development of chemical processes for extracting metals from sources long regarded as marginal or even low-grade. (See Vitro manganese process in this issue, page 50.)

Such was the message of economic geologist George Schwartz, Univ. of Minnesota, in speaking before the banquet that climaxed the first day-long technical meeting of the Twin-City Section of A.I.Ch.E. Attended by 126, the banquet was also the occasion for presentation of awards. One of these was the Presentation Award of A.I.Ch.E. given to Morton Smutz, professor of chemical engineering at Iowa State College, for having been judged best in presentation of a paper at the recent Boston Annual Meeting. George Preckshot, past chairman, was awarded a certificate (see picture) by Section chairman Al Frye (who acted as toastmaster) attesting to Preckshot's unusual service in both the organization of the Twin-City Section and the One-Day Meeting.

Past Chairman George Preckshot (left) receiving citation from current chairman A. L. Frye.

Marketing, Automation, Careers

Chemical marketing, automation and careers were subjects dealt with in simultaneous sessions—including one general papers session.

The history of the development of the market for lithium metal and compounds, with heavy emphasis on technical service to potential users, was traced by Lithium Corp.'s vice president W. M. Fenton. Fenton's advertising aide, R. P. Jones (Keystone Advertising), described his role in the development of market contacts and acceptance for Lithium Corp. products. "I learned quite early on the job that I could get from the technologists working close to product and market application development the true picture and the details which would enable my team of graphic arts people to do a job that got results," said Jones.

Turning to organization of a market development department, G. Nelson, Archer-Daniels Midland, suggested that in a company with many divisions the Market Development Dept. should be divided into groups corresponding to the divisional activities of the company. T. N. Stack of 3M then gave the engineers a short course in "do-it-yourself" market researching, and M. H. Baker of M. H. Baker Co. showed the existence of a growing demand for chemical raw materials in the North Central United States, particularly by paper mills, paint industries, agriculture, sanitary supplies, lubricating greases, and the food industry.

In the automation session, B. D. Smith, Remington Rand Univac, led off by setting down the basic concepts from which all digital computers derive, and his co-worker J. W. Tierney went a step further, predicted the role of digital techniques in the automatic chemical plant of the future, i.e. 1) business functions; 2) equation solv-

CHEMICAL ENGINEERING—PROBLEMS OF THE PROFESSION

Three local sections held major meetings in recent months on major problems in chemical engineering today. New Orleans Section tackled the problem of where the new engineers are to come from and how we will get more and better ones. Tulsa heard about engineers' "gripes." And Charleston considered Professional Standards.

Among the questions facing the chemical engineering profession today and recently discussed by local sections are: manpower, and the problem of inducing more young men to enter the profession; the dissatisfaction among engineers, particularly dissatisfaction relating to professionalism; professional standards, what they should be, how to maintain them in the face of "gripes"; and the great and growing need for more engineers.

The **New Orleans Section** (*R. H. Stewart*) at its December meeting heard its own chairman, J. R. Tusson, president of Chemoil Corp., discuss the problem of where to get more engineers, how to interest young men in engineering. Tusson emphasized that this year "considerable emphasis will be placed on the establishment of a local committee with representatives from all the scientific and engineering organizations to coordinate activities for interesting young people in scientific and engineering careers." This grass-roots committee will formulate policies and pass them on to the National Committee of H. L. Bevis in Washington. Bevis' Committee was appointed by President Eisenhower to coordinate national policies and help alleviate the technical manpower shortage.

ing in research and design; 3) help management make decisions; 4) analyze operation of the process and prepare reports; 5) control the process.

Back in the present, C. W. Swanson, Minneapolis Honeywell, reviewed *p*H control, conductivity control, and relationships between other instrumentation controls. In a practical case, R. S. Karinen, General Mills Mechanical Division, went into the instrument control used in processing soybeans, said application exists for instruments not yet developed for flow measurement and control, *p*H control, and grade classification of soybeans.

A round table session closed the meeting technical program on a highly pertinent and absorbing note. The subject: What I Do On My Job As a Chemical Engineer. Speakers came from widely diversified backgrounds, from many industries, some on the fringe of chemical processing and therefore more interesting: O. R. Videen, chief of Applied Chemistry Section, Development Department, Wood Conversion Co.; M. Smutz, head of Dept. of Chemical Engineering, Iowa State College; H. C. Crandall, technical director, Mosinee Paper Mills Corp.; J. T. Wilson, production engineer, Manganese Chemicals Corp.; and R. E. Brink, manager, Abrasive Division Patent Liaison, Minnesota Mining & Mfg. Co. Presiding at this session was N. D. Puffer, Minnesota Mining & Mfg. Co.

A General Paper session, presided over by J. C. Zemlin, Raymond Laboratories, completed the meeting.

—*W. J. Manske*

Tusson, quoting National Science Foundation statistics, showed that for every person in the U. S. in 1870 there were 3.8 persons in 1950; for each person in the labor force in 1870 there were 4.7 persons in 1950; but for each person in science, engineering and technology in 1870 there were 85 persons in 1950. And the need for scientific personnel is still rising.

Turning to the dissatisfactions of practicing engineers, G. W. McCullough, Phillips Petroleum, analyzed the major "gripes" of engineers at a February meeting of the **Tulsa Section** (*R. L. Rorschach*) held during Engineering Week in Tulsa. Most of these had some connection with the engineer's view of himself as a professional. Listing them, McCullough came up with 12 specific areas of dissatisfaction: 1) More adequate office space, work facilities, clerical help; 2) No routine or non-engineering work; 3) Salaries competitive with

(*Continued on page 132*)

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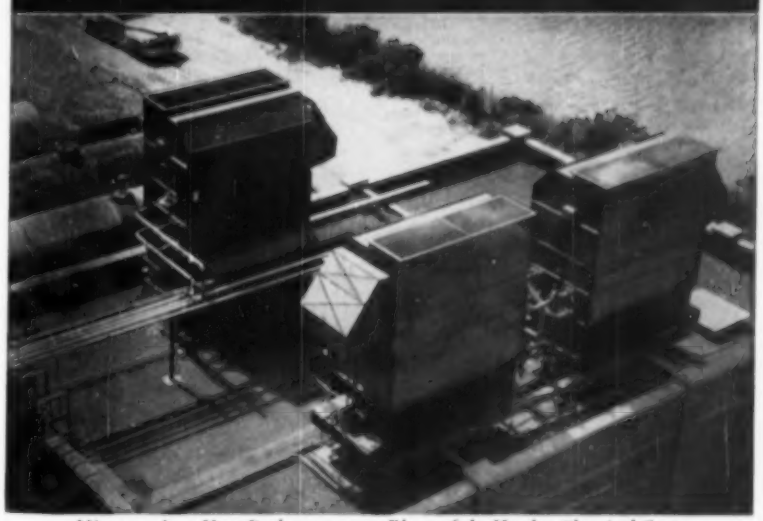

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News of the Field
FROM LOCAL SECTIONS

(*Continued from page* 131)

comparable positions in comparable companies; 4) More job rotation; 5) Chance to develop ideas and get credit for them; 6) Encouragement of membership in technical societies; 7) Reasonable permission to publish non-confidential work; 8) Reasonable employer sponsorship of attendance at technical society meetings, conferences, schools, etc.; 9) The opportunity to feel they are making a contribution to society, and can take pride in a job well done; 10) More personal contact between management and engineers; 11) A policy of promotion from within; 12) A system of job review and evaluation.

At the **Charleston Section's** (*J. R. McClain*) January meeting, R. P. Dinsmore, Goodyear Tire and Rubber, and H. W. Schulz, Carbide and Carbon, took up Professional Standards. Dinsmore, chairman of the A.I.Ch.E. committee which drafted the Professional Standards report, stated that it is the purpose of A.I.Ch.E. to take positive steps to develop a professional attitude in engineers and to publicize to employees and the public the professional status of engineers. Since the Sub-Committee he headed was dissolved in November, 1956, Dinsmore said that the problem of further development of professional standards is in the hands of the Institute's standing Professional Development Committee.

Schulz, on the committee which was given the job of drawing up a program for implementation of the Dinsmore Report, listed the short range objective of his committee as enlisting the aid of persons who could give publicity to the professional development program. The long range objectives, according to Schulz are: 1) broaden chemical engineering education; 2) unify all engineers into one engineering organization; 3) resolve questions of licensing of engineers; and 4) revise grades of membership.

AUTOMATION, COMPUTERS, NUCLEAR ENGINEERING, UNIQUE HIGH SPEED PHOTOGRAPHY FEATURE LOCAL SECTION MEETINGS

Three sections turned to the subject of automation and computers in recent local section meetings.

At the **Chicago Section** (*W. Drobot*) in January, L. F. Stutzman, Remington Rand Univac, discussed

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Computers in Chemical Engineering. Stutzman stressed that since programming of a problem for solution by computer might, and usually does, involve considerable effort and time, this approach is best suited to repetitive computations. The applicability of computers in statistical analysis and operations research is particularly apt.

Scientific Computing was the subject of R. H. Morris, Eastman Kodak, at the January meeting of the **Rochester Section** (*R. D. Boutros*). Said Morris, "The basic function of a computer is to eliminate the need for experiment by setting up mathematical models which can be solved on the computer." Morris pointed out that the cost of a particular calculation usually decreases with the speed with which it can be computed. Also, the value of a computation increases with the shorter time it takes to obtain an answer. B. McRae, also from Eastman Kodak, explained that the difference between commercial use and scientific use of the computer is that in commercial work it is usual to have a great volume of data with very few mathematical steps to go through, while scientific computing involves a small amount of data with very many computational steps to get the desired answer.

The talk of A. F. Sperry, president of Panellit, centered on the aspects of automation which are peculiar to the chemical industry at the January meeting of the **Western New York Section** (*R. L. Toole*). Whereas the machine tool and mass production industries are now going through the first or mechanization phase of automation where reduction of labor costs is the immediate objective, this is not the case in the chemical industry where continuous processing has long been common and labor costs are generally a very small fraction of total manufacturing costs. The chemical industry today is concerned with the second or "feedback" phase of automation, and the goal is higher production and greater utilization of capital assets.

Nuclear Engineering

The possible methods of using a nuclear reactor as the endothermic chemical reaction heat source in a coal gassification plant were pointed out by R. W. Ritzmann, Nuclear Products Section, Koppers Co., to the February meeting of the **Pittsburgh Section** (*G. Karnofsky*). Economics of the method were discussed and charts were presented showing the effects of steam temperature and heat recovery

(*Continued on page* 134)

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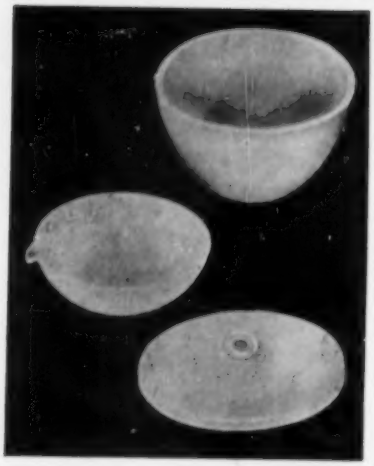

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News of the Field
FROM LOCAL SECTIONS

(*Continued from page* 133)

on the threshold economics. Ritzmann emphasized that such a reactor is a long-term project, estimated it would take five to ten years to develop.

In the nuclear field itself, Union Carbide Nuclear does not foresee immediate profit, according to George Jenkins, manager of chemical processing for Union Carbide Nuclear, speaking to the February meeting of the **Knoxville-Oak Ridge Section** (*R. W. Horton*). But considerable optimism was expressed by Jenkins regarding the present efforts in chemical processing of reactor fuels for the Westinghouse-Pennsylvania Electric PAR homogeneous reactor and the liquid metal fuel reactor which is being developed by Babcock and Wilcox. The possibility of entering the processing field with a unit capable of handling all types of reactor fuels is being intensively explored, and seems to hinge largely on the potential market for isotopes separated from fission products.

Precious Metals

Oklahoma Section (*E. R. Beck*) heard B. Seligman, Baker and Co., discuss platinum metals in the Chemical Industry. Precious metal catalysts are important to the manufacture of hydrocyanic acid, nitric acid, dihydrostreptomycin, and purified gas. They are also used importantly in the reforming and isomerization of hydrocarbons. In addition to their use as catalysts, platinum metals are used in the fabrication of clad equipment, rupture disks, spinnerettes, contacts and laboratory equipment.

Also Meeting

Washington-Oregon Section's (*L. N. Johanson*) December meeting was a plant trip through Kaiser Gypsum's Seattle plant. In the evening, Blewett and Weightman of Kaiser spoke on the various processing methods used in the gypsum industry. . . **Memphis Section** (*T. A. Feazel*) in December heard C. G. Blatchley, Schutte and Koerting, discuss jet ejectors and jet vacuum pumps. . . Fluid Solids was the subject at **Pittsburgh Section's** (*G. Karnofsky*) December meeting. Speaker D. D. MacLaren of Esso Research and Engineering attracted 120 members and guests to this subject of vital interest to Pittsburgh area engineers. . . **Twin City Section** (*E. J. Murray*) held a business meeting and dinner in December, were entertained

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J. W. Westwater, Univ. of Illinois, speaking to the February meeting of the Alton-Wood River Section, explained that heat transfer to boiling liquids is a poorly understood form of heat transfer which is at last receiving serious attention because of the large heat fluxes possible with boiling liquids. In this connection, photography is a powerful tool for the study of boiling, could be applied to other nucleation phenomena. Westwater showed a high-speed motion picture, taken at 4,000 frames a second, to demonstrate the great difference between nucleate, transition, and film boiling. Still photographs illustrated the details. The above picture, taken at 10^{-4} second exposure, is benzene in film boiling outside a vertical tube of ½-inch O.D. at a film T of 287° F.

by Roland Cody with feats of magic. . . At the **Akron Section** (*E. W. Campbell*) in December D. D. Frederick, chief design engineer, Autoclave, Inc., discussed high pressure equipment design. Frederick stated that simplicity, versatility and safety are the three important elements of a good high pressure design. . . **Rhode Island Section** (*J. L. Campanella*) considered Water as a Chemical Raw Material at its December meeting. Speaker H. A. Faber, Office of Engineering Services in Washington, D. C., gave a statistical evaluation of our water resources and requirements, refinement methods and recovery. . . **Idaho Section** (*W. L. Chase*) had a lively year, including being granted section status, and the new section then rounded out the year by combining chemical engineering with local problems in a talk on Potato Processing at its December meeting by Miles Williard, Rogers Bros. Seed Co. . . Gasoline and the Operation of a Modern Automobile was the subject under discussion at **Texas Panhandle Section** (*C. M. Oktay*) in January.

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people

McIntyre

Glenn H. McIntyre retires from his position as vice-president and technical director of the Ferro Corp. to assume active management of the National Spectrographic Laboratories, Cleveland, Ohio.

Glen D. Schaaf promoted to post of senior technical man at Welland, Ontario, plant of B. F. Goodrich Canada, Ltd.

Changes in Diamond Alkali's Engineering Department include appointment of **Robert C. Sutter** as operations manager, Chlorinated Products Division, and naming of **William J. Lightfoot** to succeed Sutter as assistant director of engineering.

New additions to staff of Aerojet-General Nucleonics include **S. Nakazato** as senior nuclear engineer and **Robert H. Chesworth** as nuclear engineer.

John F. Blumenfeld joins General Electric Co.'s Chemical Development Department as development engineer.

Newly promoted at General Tire & Rubber Co., Chemical Division, Mogadore, Ohio, plant are **R. W. Laundrie** as technical superintendent and **L. E. Gressingh** as chief process engineer.

Emil F. Werly joins staff of the Chemical Engineering Division, Midwest Research Institute, Kansas City, Mo.

Linde Air Products Co. appoints **Myles K. Towne** to staff of their Tonawanda, New York, Laboratories. He will work with the Molecular Sieves Development Group.

John W. Cosier named chief product engineer of the Pfaudler Co., Rochester, N. Y.

Mitchell

Stauffer Chemical Co. announces appointment of **Charles W. Mitchell** as vice-president of the company and general manager of the Nyotex Chemicals Division.

Russell G. Dressler, expert in evaporation control research, has been retained by Archer-Daniels-Midland Co., Minneapolis, as consultant on a large water conservation project.

Babcock & Wilcox announce appointment of **Robert K. Allen** as superintendent of product development at their Alliance, Ohio, research center.

Charles E. Starr, Jr., named to new post of manager of Technical and Public Information by Esso Research and Engineering Co.

Kennametal, Inc., Latrobe, Pa., announces appointment of **B. Clark Boeckeler** as assistant for advanced planning and development.

Arthur A. Moore, former assistant manager of the Research Administration Section, becomes manager, Business Services Section, of the Koppers Co. Research Department.

Chas. Pfizer & Co. elects **Allan J. Greene** administrative vice-president and member of the executive committee. Mr. Greene spoke before the recent (March 3-6) White Sulphur Springs National Meeting of the A.I.Ch.E. on "The Future for Drugs and Biochemicals."

Recent additions to the staff of the Whiting Research Laboratories of the Standard Oil Company (Indiana) are **Samuel C. Spencer** and **William Resnick.**

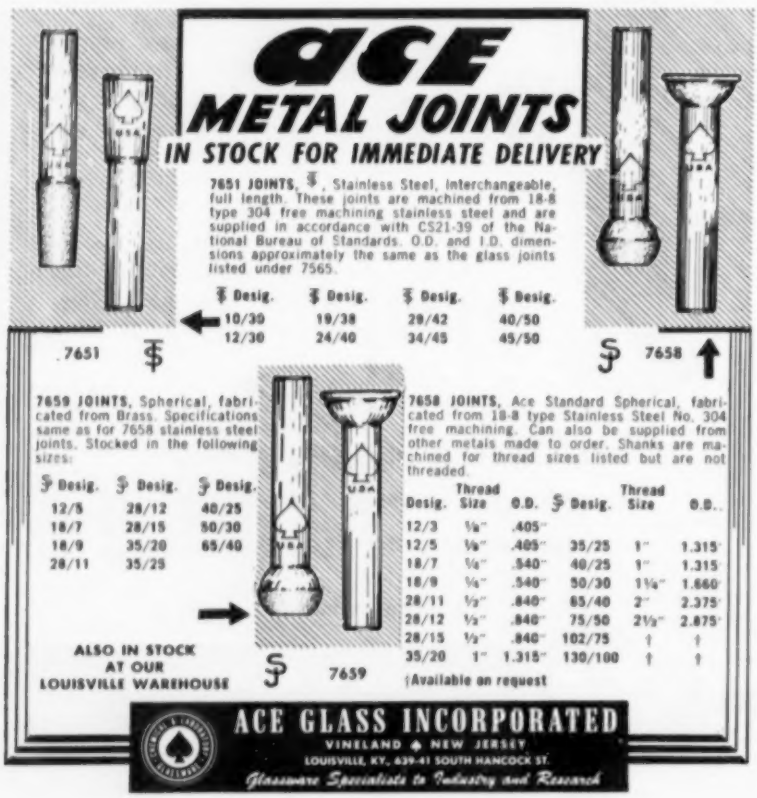
Atlas Powder Co. names **James H. Perry** as senior chemical engineer in their chemical engineering department.

Arthur B. Tillman becomes Electro Chemicals Division operations manager for Diamond Alkali Co., Cleveland, Ohio.

Union Carbide Nuclear Company names **Adolph Q. Lundquist** to post of vice-president. Mr. Lundquist joined Union Carbide in 1942.

B. D. Thomas will be the new director of Battelle Memorial Institute, Columbus, Ohio. Mr. Thomas will be responsible for Battelle's research operations in the United States and Europe.

Frederick W. Gander becomes director of the Yerkes Research Laboratory, major research center of Du Pont's Film Department.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Desig. Desig. Desig. Desig.
10/30 19/38 29/42 40/50
12/30 24/40 34/45 45/50
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7658
7659 JOINTS, Spherical, fabricated from Brass. Specifications same as for 7658 stainless steel joints. Stocked in the following sizes:
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12/5 28/12 40/25
18/7 28/15 50/30
18/9 35/20 65/40
28/11 35/25
7658 JOINTS, Ace Standard Spherical, fabricated from 18-8 type Stainless Steel No. 304 free machining. Can also be supplied from other metals made to order. Shanks are machined for thread sizes listed but are not threaded.
Desig. Thread Size O.D. Desig. Thread Size O.D.
12/3 1/8" .405"
12/5 1/8" .405" 35/25 1" 1.315"
18/7 1/4" .540" 40/25 1" 1.315"
18/9 1/4" .540" 50/30 1 1/4" 1.660"
28/11 1/2" .840" 65/40 2" 2.375"
28/12 1/2" .840" 75/50 2 1/2" 2.875"
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New appointments in Hercules Powder Company's Explosives Department include **E. St. Pierre Bellinger** as manager of Ketona Chemical Corp., Birmingham, Alabama, and **Gordon M. Hoffman** as assistant manager, Missouri Ammonia Works.

Charles L. Thomas, director of research and development of the Sun Oil Co., elected director-at-large of the American Chemical Society. The ACS also announces award of their Washington (D.C.) Section's Hillebrand Award for 1957 to **Francis O. Rice,** head of the department of chemistry at Catholic University.

Union Carbide Nuclear appoints **Frank W. Hurd** as director of research. Mr. Hurd has been identified with Union Carbide's activities in the atomic energy field since 1943, when he joined the Manhattan Project as a senior research scientist.

Hurd

John R. Brown, Jr., is elected vice-president for research and development at Spencer Chemical Co. Mr. Brown was previously managing director of research and development.

New members of the technical organization of the Development Department at the South Charleston, W. Va., plant of Carbide and Carbon Chemicals Co. are **D. O. Daley, T. E. Kennell, B. L. Connelly, R. A. Mussey, A. C. Oberton,** and **D. H. Ashmus.**

Robert E. Pope, doctoral candidate in chemical engineering at Univ. of Kansas, is named Grand Scribe of Theta Tau, national engineering fraternity.

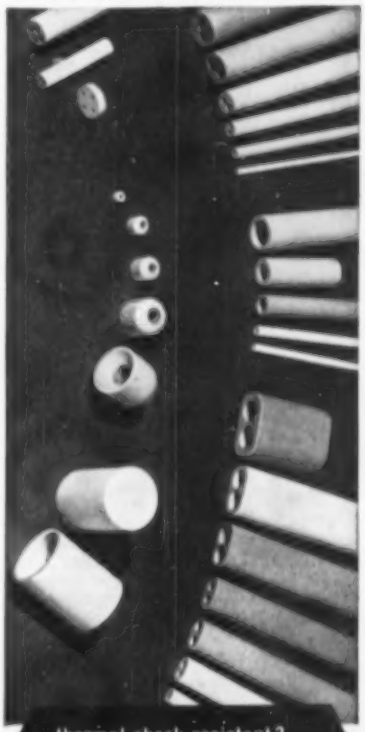
Goodyear Tire and Rubber Co. names **James A. Merrill** as associate director of research and development.

John A. Adams becomes manager of materials for Silicone Products Department, General Electric Co. Other changes in the department include appointment of **Richard D. Rice** as general foreman.

Vitro Uranium Co. elects **William B. Hall** as president and general manager. Mr. Hall was connected with Sinclair Refining Co. and Southern Oil Co. before joining Vitro in 1951.

(Continued on page 138)

Insulators for Thermocouples



thermal shock resistant?
mechanical strength?
high temperature resistant?

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Cox

Henry L. Cox joins Western Precipitation Corp. as consultant on chemical processing. Mr. Cox was formerly vice president in charge of research and development for Corn Products Refining Co.

H. B. Coons is appointed superintendent of Niagara Falls plant of Carbide and Carbon Chemicals Co.

New members of Research and Development Department of Ethyl Corp. in Baton Rouge, La., are **James J. Mullen** and **Robert W. Harrell.**

William G. Copeland becomes general manager of the Texas Company's Refining Department. Mr. Copeland joined Texaco in 1927.

Major appointments at Solvay Process Division, Allied Chemical & Dye, are **Raymond C. Baxter** as chief engineer, **Elwood F. Booth, Jr.,** as assistant chief engineer, and **Robert H. Reed** as process development manager.

Commercial Solvents elects **J. F. Dudley** and **Graham W. McMillan** as vice-presidents. Mr. Dudley will head the company's production and engineering activities, while Dr. McMillan will be responsible for the company's research and development program.

Kapranos

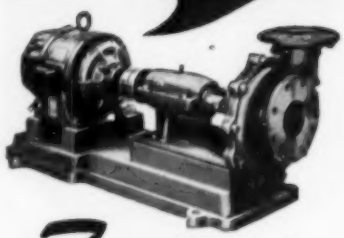
S. William Kapranos assumes post of vice-president for product planning for Mead Johnson & Co. Mr. Kapranos was previously connected with Booz, Allen & Hamilton, management consultants.

William L. Ferrall joins staff of Esso Research and Engineering Co. Mr. Ferrall comes to Esso Research from M. W. Kellogg Co.

American Alcolac Corp. names **Alvin Holzberg** to staff of its Development Department. Mr. Holzberg was formerly with International Minerals and Chemical Co. and National Dairy Research.

(*Continued on page* 140)

Custom-built for EFFICIENT DEPENDABLE SERVICE



Frederick

SSV PUMPS

Enclosed Impeller and Open Impeller Types

You're sure of maximum service and output with minimum maintenance or production down time with Frederick SSV Centrifugal Pumps because each pump is custom-made to fit your particular operation—whatever the consistency or type of liquid you're moving.

SSV PUMP FEATURES

- **Pump sizes from 1" to 4" discharge openings.**
- **Pump capacities from 50 up to 700 U.S. GPM.**
- **Heads from 30 up to 220 feet.**
- **Pumps speeds can be varied to suit the driving media and operating conditions.**

CONSTRUCTION ADVANTAGES

Pump casings are vertically split for easy accessibility. Mounted on a swivel to permit placing discharge in any desirable position. Pump openings, both suction and discharge, flanged to permit easier connection and disconnecting to joints. One-piece impellers, securely attached to shaft by stout key and lock nut, or threaded, give long service. Pump bearings mounted in sturdy frame horizontally split for easier accessibility. Extra long stuffing box provides for oversize stuffing. Mechanical seal also available for minimum leakage. Pump coupling flexible for direct connection to drivers or can be arranged for belt drive. Pump speed, pump openings, etc. are selected to suit your particular requirements.

Write for Bulletin No. 107

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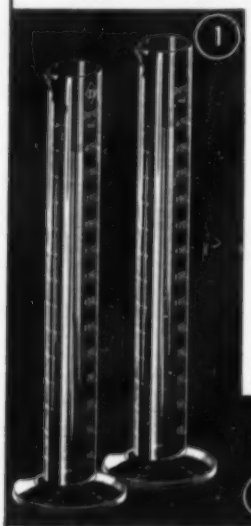
make sure...
make the "two-way" test



Make sure that you get the highest quality laboratory glassware for the lowest possible price by making the "TWO-WAY" Test.

TO MAKE THE "TWO-WAY" TEST !

STEP 1. Obtain samples of several advertised brands of laboratory glassware. Be sure to include a piece of Doerr Diamond D Blue Line. Devise the most rigid tests you can think of and evaluate each brand on the basis of these tests. Tabulate the results.

STEP 2. Now, **compare the prices.** You will find that the Doerr Diamond D Blue Line is your best buy . . . offering the highest quality for the lowest possible price.

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NEW BIN LEVEL INDICATOR

New ROTO-BIN-DICATOR®
Motor driven paddle-type bin level indicator

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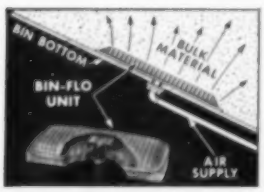

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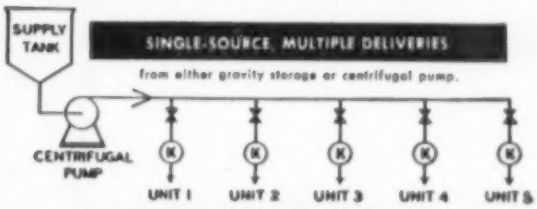
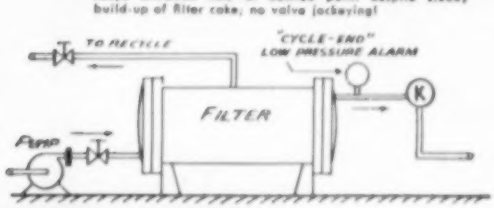
Here's an answer to liquid flow rate control that should appeal to processing, maintenance and accounting men alike. Inlet and outlet piping are the *only* connections; no linkages, control air or electronics are required. Just connect the flow piping and set the desired flow rate; nothing else is required. When inspection or maintenance are necessary, just lift the working parts from the case, which remains in the piping.

KATES direct-acting regulators combine with inexpensive centrifugal pumps or gravity feeds for precision control of blending, liquid circuits, process additives, or coolants—more reliably and at less cost than comparable control systems. Pressure jumps or drops of 125 psi, either upstream or down, are compensated internally —without hunting or lagging. Check over the following typical applications, then write for the entire story.



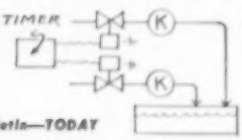
PRESSURE FILTRATION CONTROL

keeps filtration rate at desired point despite steady build-up of filter cake; no valve jockeying!



BATCH PROCESS MEASUREMENT

with nothing more than a timer and solenoid valves feeding through Kates regulators!



Write for Technical Bulletin—TODAY

Kates

W. A. KATES COMPANY
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people

Bernard J. Gaffney has been named New York manager of the Rust Engineering Co. Prior to joining the Rust organization, Mr. Gaffney was connected with Chemical Construction Corp. as sales manager, industrial chemical processes.

Gaffney

Theodore A. Mangelsdorf becomes vice-president of the Texas Co. Mr. Mangelsdorf joined the Texas Co. in 1933 as a chemical engineer.

Robert D. Lloyd and **Leland M. Reed** have joined the High Energy Fuels Organization of Olin Mathieson Chemical Corp. **William H. Wood** has joined the organization as a process instrument engineer.

Walter H. Salzenberg, formerly general manager of the Grasselli Chemicals Department, becomes assistant general manager of DuPont's Polychemicals Department.

Alcoa Research Laboratories announces appointment of **Robert H. Brown** as assistant director. Mr. Brown joined Alcoa in 1931.

New vice-presidents at Lithium Corp. of America are **J. Dean Herman, J. D. Campbell** and **Walter M. Fenton.** Mr. Fenton was a speaker at the recent Twin Cities one-day meeting of the A.I.Ch.E.

David A. Strang joins staff of the Research and Development Department of Procter & Gamble.

Allen N. Smith to head new chemical engineering program at San Jose State College. Mr. Smith was formerly associate professor of chemical engineering.

Roberts

Edward S. Roberts, formerly vice president and chief engineer of Chemical Construction Corp., joins Barsky and Strauss, Inc., chemical consultants.

Kaiser Engineers announce appointment of **Robert J. Wolf** as division manager.

American Section of the Society of Chemical Industry announces that **Clifford F. Rassweiler,** vice-chairman and vice-president for research and development of Johns-Manville Corp., has been chosen to receive the Chemical Industry Medal for 1957 "for conspicuous services to applied chemistry."

Rassweiler

Robert E. Maples promoted to assistant superintendent in Baltimore for Continental Oil Company's petrochemical department.

Retirement of **Donald S. Cryder,** professor and head of the department of chemical engineering at Pennsylvania State University, is announced.

Bernet S. Swanson has been promoted to the rank of associate professor of chemical engineering at Illinois Institute of Technology, Chicago.

Diamond Alkali appoints **Robert E. Frey** to position of assistant works manager—operations at their Painesville, Ohio, works.

(*Continued on page* 146)

PLANNING IN SPACE!

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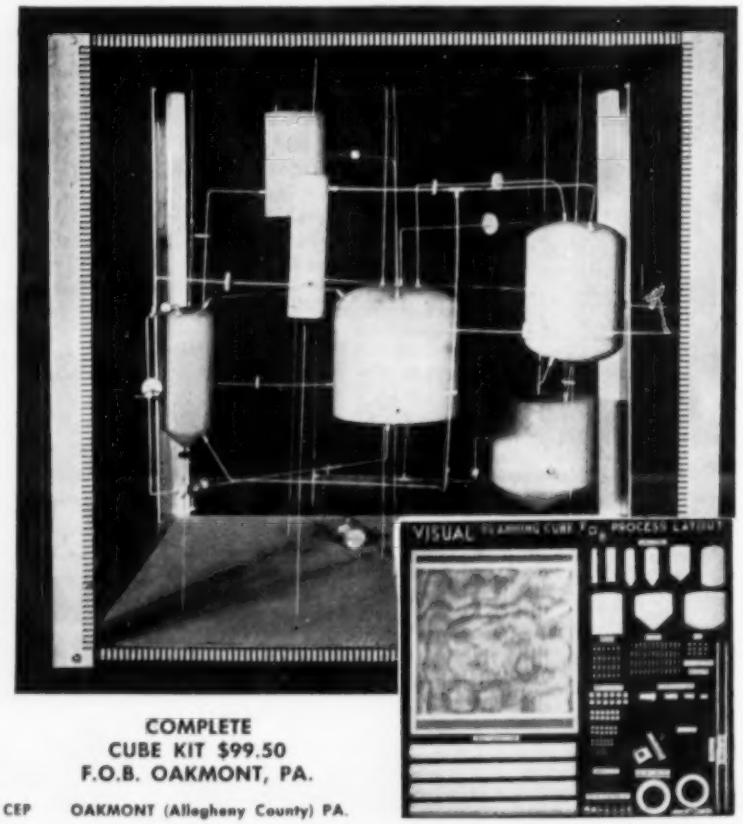

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With Wilmad Precision Bore Stirrers, you can easily replace a damaged part. All Wilmad stirrers are consistently uniform and held to extremely close tolerances assuring the interchangeability of all parts. It is no longer necessary to discard damaged stirrers if you specify Wilmad.

We stock a complete line of stirrers in both Standard Taper and Spherical Joints to fit all sizes of flasks.

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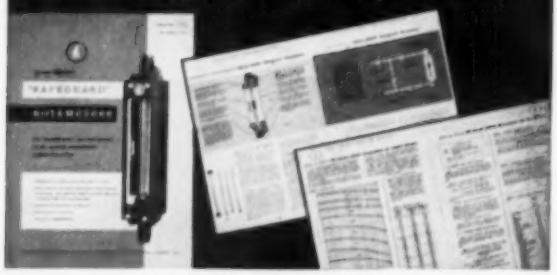
NEW "SAFEGUARD" ROTAMETER BULLETIN
Gives Step-by-Step Sizing Instructions



Immediately available on request, new SK Bulletin 18RG provides valuable information for anyone who must measure fluid rate-of-flow accurately and safely. The bulletin describes SK's line of "Safeguard" Rotameters—includes complete data on application, construction, materials available, installation, and operation.

User benefits are recorded in detail. Of great value are the simplified, step-by-step instructions for sizing and selecting Rotameters for liquid and gas rate-of-flow measurement. Capacity tables are included.

For a copy of Bulletin 18RG, write to us at the address below.

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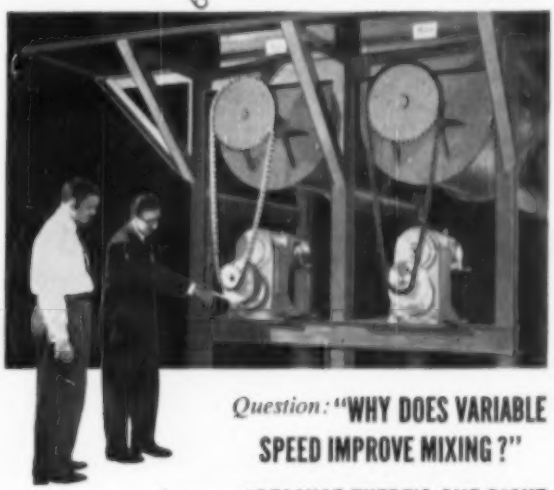
VARIABLE SPEEDS FOR VARYING NEEDS---MIXING



Question: **"WHY DOES VARIABLE SPEED IMPROVE MIXING?"**

Answer: **"BECAUSE THERE'S ONE RIGHT SPEED FOR EVERY MIXING CONDITION—"**

for example:

VISCOUS MATERIALS-Where dry ingredients are mixed or reacted with vehicles or binders, the materials may go through a plastic state in their reaction; therefore variable speed increases or decreases rpm speed to accommodate the process requirements.

TEMPERATURE VARIATIONS-When liquids or semi-solids undergoing mixing lose heat, the speed of the mixer may require reduction progressively or in steps. A Varidrive will give you the precise speeds needed at different levels of temperature.

BATCH BLENDING-Different consistencies of batch materials may require slow speed to start, but when they become integrated, higher speed may be applied to reduce time. The same mixer can be used for processing materials of widely varying consistencies by powering it with a Varidrive. Thus you save space and extra equipment.

EXPERIMENTAL PROCESSES-You may want to mix new compounds or blends to determine how slow or fast you should make up the batch. Only by variable speed can you get the sensitive rpm needed for experimenting. Varidrive is the answer.

INCREASED VERSATILITY-A mixer can be used for many operations with variable speed, whereas a single-speed will restrict its use. A Varidrive gives a mixer its full potential of performance so that you may be able to avoid purchase of extra mixers.

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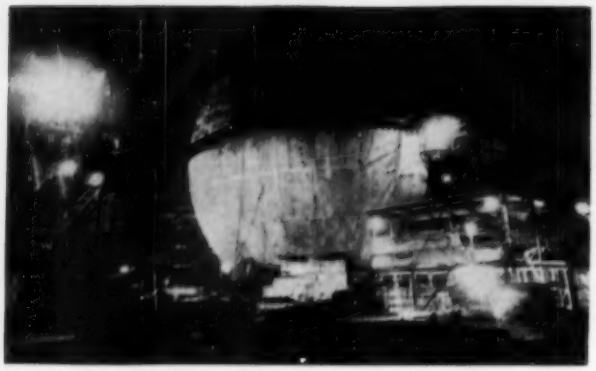
CEP CAMERA

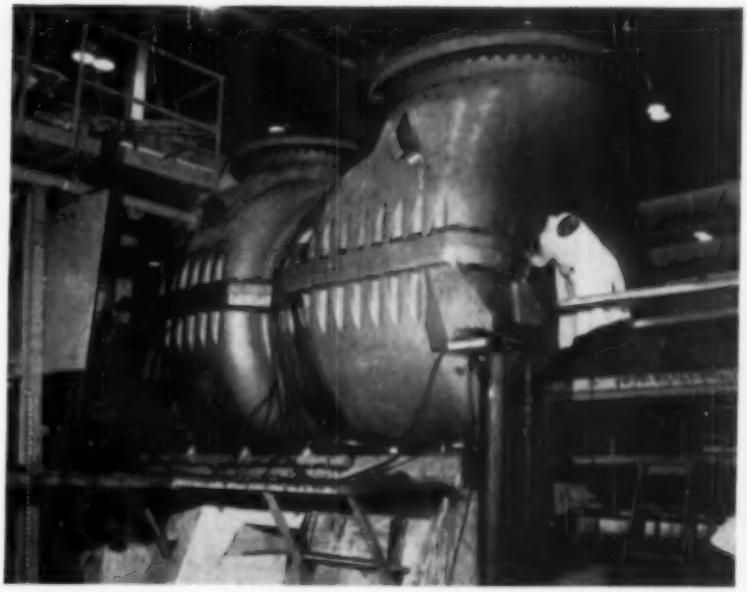


RADIANT REACTOR at Dounreay, Scotland, is fast breeder, will be housed in 135-foot hermetically sealed sphere.

CANADIAN DEVELOPMENTS—This $12 million chlorine-caustic soda Hooker Chemicals Ltd. plant is under construction at Burrard Inlet, North Vancouver, B. C., will be completed in June. The first chlor-alkali plant in Western Canada, this will also be the first Hooker plant to use the new larger Hooker Type S-3B cell producing chlorine and caustic from purified brine. At present this type of cell produces more chlorine than any other type. The plant is designed for an initial daily capacity of 100 tons of chlorine, 110 tons of caustic soda, and a million cubic feet of hydrogen. In right background is $4 million-plus new sodium chlorate plant of Electric Reduction Co. of Canada, Ltd.

UNITY dinner, part of Engineers' Joint Council 3rd General Assembly, sees at head table (left to right) A.I.Ch.E. president J. H. Rushton; J. W. James, president ASHAE; M. S. Coover, president AIEE; and W. F. Ryan, president AIME.

POPULAR REFRESHER course run by Western New York Section, A.I.Ch.E., gets regular turnout of 145 for weekly two-hour classes on distillation techniques.



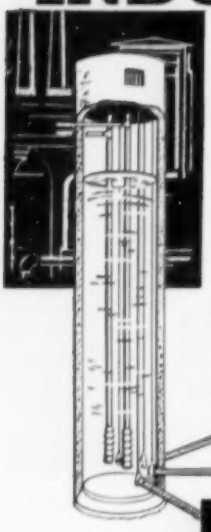
BIG AXIAL COMPRESSOR for use in Houston butadiene plant of Petro-Tex Chemical Corp. Each axial serves as first of three stage compression of butene; subsequent stages being centrifugal with final discharge at 160 lb./sq.in. Axial's capacity is 172,500 cu.ft./min.; is driven by steam turbine of 4,500 h.p. Total weight 45 tons. (Courtesy Carrier.)

N. Y. SECTION $500 STARTS ENGINEERING CENTER DRIVE. Left to right: T. M. Jackson, Jr. (vice-chairman) and J. F. Lawrence (chairman) of N. Y. Section, A.I.Ch.E., deliver to W. J. Barrett, president, United Engineering Trustees, check for $500 as the first contribution to the fund drive for a National Engineering Center, as W. F. Thompson, chairman of U.E.T.'s Real Estate Committee, looks on. Lawrence termed the contribution a "symbolic gesture which we hope other engineering and business groups, plus individuals, will follow."

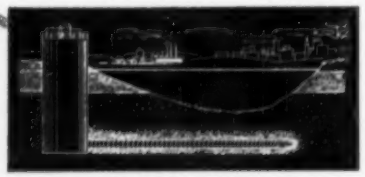
AWARD for best presentation of paper at Boston Annual Meeting is received by Morton Smutz (right), Iowa State College. Certificate is being tendered by Al Frye, chairman, Twin Cities Section, A.I.Ch.E., during one-day meeting at Minneapolis January 31.

TECHNICAL MAN-OF-YEAR
R. B. Filbert, Jr., Battelle chemical engineer chosen for 1956 honor by Columbus (Ohio) Technical Council at dinner celebrating National Engineers' Week. Award included check for $50. Filbert was chairman of Central Ohio Section, A.I.Ch.E., during 1955, also co-chairman of regional one-day symposium on industrial gases.

INDUSTRIAL *water...* a job for the RANNEY METHOD



Conventional Collector. Proven by industries the world over, the collector that yields more naturally filtered water, with less equipment, less personnel, and fewer pumps than any other conventional collector.



Infiltration Gallery. The gallery, engineered by Ranney, provides industry a low cost water supply. The gallery provides large quantities of clear non-turbid water in a revolutionary yet economical way, and it requires no maintenance.

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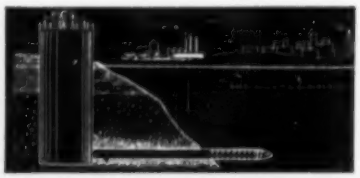
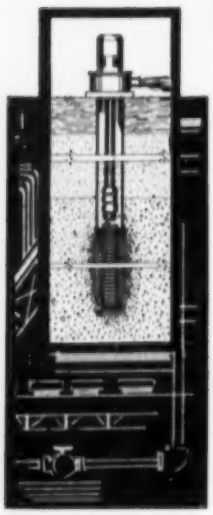


Ranney Intake. The Ranney Intake, already has proven that plants and factories can obtain surface water both efficiently and economically. The Ranney Intake can usually fit into the design of your engineering department or consultant.



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CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 8 of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members and Associate Members will receive careful consideration if received before March 15, 1957, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

Member

Allen, Fraser H., *Oklahoma City, Okla.*
Allen, William J., Jr., *Army Chemical Center, Md.*
Bauer, William C., *Green River, Wyo.*
Benson, R. E., *Eden, N. Y.*
Bethea, Sam Rice, *Baytown, Tex.*
Brewer, John F., *Baton Rouge, La.*
Cagen, Melvin S., *Rochester, N. Y.*
Casselman, T. E., Jr., *Boston, Mass.*
Ciskowski, Joseph M., *Rahway, N.J.*
Cornell, Vernon A., *New York, N. Y.*
Dalla Valle, J. M., *Atlanta, Ga.*
Day, John R., *Penns Grove, N. J.*
Ellington, Rex T., *Chicago, Ill.*
Glocker, Edwin M., *Baltimore, Md.*
Gutliph, Earl W., *Memphis, Tenn.*
Halbach, W. C., Jr., *Painesville, Ohio*
Heinrich, Raymond L., *Baytown, Tex.*
Hurd, Vincent N., *Pittsburgh, Pa.*
Joyce, Joseph J., *Pittsburgh, Pa.*
Kelley, Carl S., *Bartlesville, Okla.*
Kesler, George H., *Worthington, Ohio*
King, Walter C., *Pittsburgh, Pa.*
Lam, Henry W., *Philadelphia, Pa.*
Lipworth, M. F., *Linden, N. J.*
Martin, Roblee B., *Ste. Genevieve, Mo.*
O'Brien, Leo J., *Crystal Lake, Ill.*
Pedersen, John Harry, *Long Beach, Calif.*
Riggin, Cecil W., Jr., *Memphis, Tenn.*
Satterfield, Charles N., *Cambridge, Mass.*
Serakis, Peter M., *Pittsburgh, Pa.*
Sieger, John S., *Pittsburgh, Pa.*
Sklarz, William A., *Rahway, N. J.*
Spitz, Albert W., *Elkins Park, Pa.*
Tassoney, Joseph P., *McKeesport, Pa.*
Tily, William E., *Westfield, N. J.*
Williams, Edwin T., *State College, Pa.*
Wolf, Joseph E., *Whiting, Ind.*
Wolkoff, Jasper, *Park Forest, Ill.*
Yerazunis, Stephen, *Troy, N. Y.*

Associate Member

Abbrecht, Peter H., *Birmingham, Mich.*
Armstrong, William S., *North Hills, Pa.*
Bergman, Richard I., *Plainfield, N. J.*
Berner, George W., Jr., *Baytown, Tex.*
Boushka, William M., *Lorain, Ohio*
Bugbee, William N., *Charleston, W. Va.*
Comolli, Ferdinand M., *Wilmington, Del.*
Dugan, W. J., *So. Charleston, W. Va.*
Erskine, Harold L., Jr., *Pittsburgh, Pa.*
Field, David E., *Philadelphia, Pa.*
Freiheiter, Felix, *Brooklyn, N. Y.*
Getz, Donald H., *Montvale, N. J.*
Gross, Floyd M., *Barberton, Ohio*
Hammock, Thomas V., *Kingsport, Tenn.*
Harrison, Charles L., *Camden, Ark.*
Hatfield, Raymond C., *Houston, Tex.*
Hogsett, Duane F., *Bartlesville, Okla.*
Hulswitt, C. E., *Cleveland, Ohio*
Johnson, Berry M., *Andrews, Tex.*
Kellard, James D., *Venezuela, S.A.*
Kogstad, Rolf E., *Brea, Calif.*
Lischer, Robert E., *St. Louis, Mo.*
Martin, Bruce A., *Baytown, Tex.*
Martin, G., *Moscow, Idaho*
Morlock, K. G., *Whiting, Ind.*
Nussbaum, Stuart, *Bedford, Mass.*
Nygren, Paul G., *Nitro, W. Va.*
Perkins, Dimmitt, *Orange, Tex.*
Perry, Kenneth W., *Bauxite, Ark.*
Phalen, Bruce S., *Fredericksburg, Va.*
Plaster, William E., *Bartlesville, Okla.*
Presley, Robert L., *Baytown, Tex.*
Richardson, Jean S., *Pine Bluff, Ark.*
Russell, Charles R., *Bakersfield, Calif.*
Ryland, J. R., *El Dorado, Ark.*
Sauer, Henry J., *Pittsburgh, Pa.*
Schatz, Ralph H., *Westfield, N. J.*
Searcy, John S., *Decatur, Ala.*
Shafranek, Lennis F., *Wilmington, Del.*
Shannon, Robert F., *New London, Conn.*
Shirley, William H., *New Martinsville, W. Va.*
Sloan, Clarence T., Jr., *Washington, Pa.*
Smith, Philip F., *Lake Jackson, Tex.*
Stankis, Glenn A., *Baytown, Tex.*
Stiff, D. A., *Highland, Ind.*
Storrs, John H., *Woodstown, N. J.*
Swartz, Benjamin, *Elizabeth, N. J.*
Tabar, William J., *So. Charleston, W. Va.*
Tate, William M., *Louisville, Ky.*
Tindall, Bobby Max, *Texas City, Tex.*
Vonder Heiden, Frederick H., *Pottsville, Pa.*
Vredeveld, Donald R., *Institute, W. Va.*
Wagstaff, J. B., *Murrysville, Pa.*
Wilson, Robert Elwood, *Dayton, Ohio*
Wimpfheimer, Leonard, *Columbus, Ohio*
Winn, William D., *Lake Jackson, Tex.*
Wisniach, J., *Detroit, Mich.*
Zeff, Jack D., *Chicago, Ill.*

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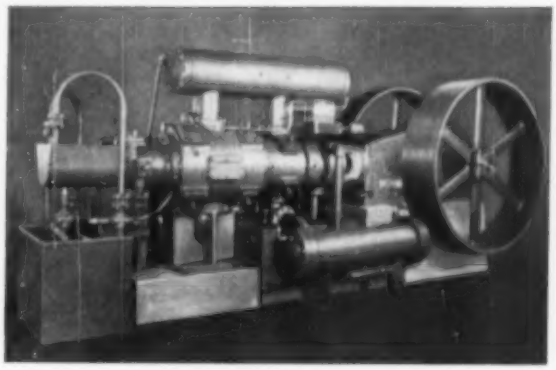
NORWALK

HIGH PRESSURE COMPRESSOR



The five stages on this heavy-duty tandem compressor require less horsepower and develop less heat than in four stages in producing 3000 lb. per square inch pressure in capacities up to 31,000 cfh.

Frames with double row roller bearings, reversible ring plate valves, force feed lubrication, generous intercooler coils are some of the features that make this horizontal compressor compact, sturdy and efficient to operate and maintain.

Every Norwalk compressor is test-run for eight hours at the factory, then taken down for complete inspection before re-assembly and shipment.

Norwalk makes compressors from single stage to six stages, from 125 to 25,000 lb. psi. Catalog on request.

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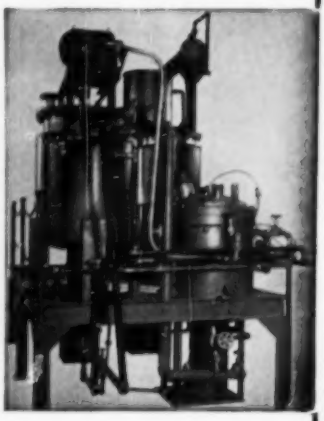
Artisan is an outstanding source for your Pilot Plant and Special Continuous or Batch Complete Processing Unit.



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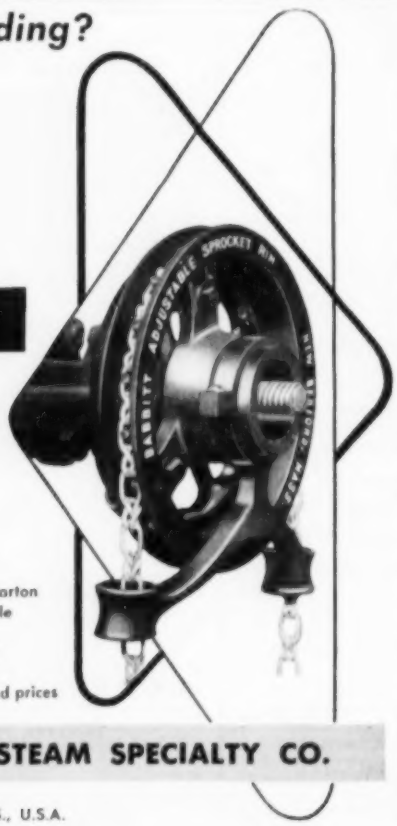

Babbitt **STEAM SPECIALTY CO.**

6 BABBITT SQUARE, NEW BEDFORD, MASS., U.S.A.

people

Linde Air Products Co. names **H. T. Ross** as vice-president for engineering. Mr. Ross joined Linde in 1928.

New staff members at Monsanto Chemical include **Joseph Jaffe**, research department of Inorganic Chemicals Division at Everett, Mass., **Norman L. Case**, sales department, Inorganic Chemicals Division at St. Louis, **Silvan B. Lutkewitte, Jr.**, technical services at William G. Krummrich Plant in Monsanto, Ill., and **James R. Savage**, technical services department at John F. Queeny Plant in St. Louis.

Frye

E. E. Frye becomes vice-president and manager of the Petroleum Division for J. F. Pritchard and Co., Kansas City. Mr. Frye has been with the Pritchard organization since 1947.

Sherwood L. Fawcett named assistant manager of Department of Physics at Battelle Memorial Institute.

the chemical engineer in

MARKETING

W. D. Lahey named sales manager—adhesives for B. F. Goodrich Industrial Products Co. Mr. Lahey joined B. F. Goodrich Chemical Co. in 1945.

Petrick

Edward H. Petrick, at present general sales manager of West Virginia Pulp & Paper Co., will become vice-president in charges of sales for Brown Co.

Mervyn T. Walsh will manage muriatic acid sales for the Chlorinated Products Division of Diamond Alkali Co.

Organic Chemical Sales Department of Emery Industries, Inc., names **George R. Williams** as sales representative in the New York City area.

A. R. Olsen has been appointed sales manager of the Cellulose and Chemicals Division of Hercules Powder Company's Virginia Cellulose Department.

(Continued on page 154)

CLASSIFIED SECTION

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Men with refinery or chemical plant experience who are familiar with process design and estimating of heat exchangers and fractionation columns. Responsible positions with an outstanding manufacturer. Good salaries. Profit-sharing retirement plan. Allowance for moving to Southern California. Send a summary of your experience and interests to F B Stratford, Head of Personnel, C F BRAUN & CO, Alhambra, California.

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Resumes will be carefully evaluated, in confidence. Please write complete details including salary requirements to L. H. Hitchens.

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Work consists of translating process requirements into completed operating pilot plants and includes mechanical design, proper application of equipment, instrumentation, cost estimation, scheduling, materials procurement, field supervision of construction, initial operating shake-down, and new equipment development.

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ENGINEERS

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Assignments in our Process Engineering Department for engineers with eight or more years of experience cover process design, selection of processing steps, and economic evaluation of processes. Other work may include market analysis, industrial surveys, and technical assistance to sales. Send a summary of your experience and interests to F B Stratford, Head of Personnel, C F BRAUN & CO, Alhambra, California.

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are offered opportunity to advance professionally in diversified growth company

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- **PROJECT ENGINEERING:** To coordinate the engineering, design and construction of complete plants.
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- **DESIGN ENGINEERING:** Process equipment, pressure vessels, piping, structural, plant layout, electrical, instrumentation.
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- **RESEARCH AND DEVELOPMENT:** To explore new horizons in processing and equipment design. Analytical, experimental, design, pilot plants.
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Advertisements in the Classified Section are payable in advance at 20¢ a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates. Prospective employers and employees in using the Classified Section agree that all communications will be acknowledged; the service is made available on that condition. Boxed advertisements are available at $17 a column inch. Size of type may be specified by advertiser. Answers to advertisements should be addressed to the box number, Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone: COlumbus 5-7330. Advertisements for this section should be in the editorial offices the 15th of the month preceding publication.

Scientists ...

Engineers

A message from M. A. Schultz, Project Manager

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(Continued on page 152)

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(Continued from page 150)

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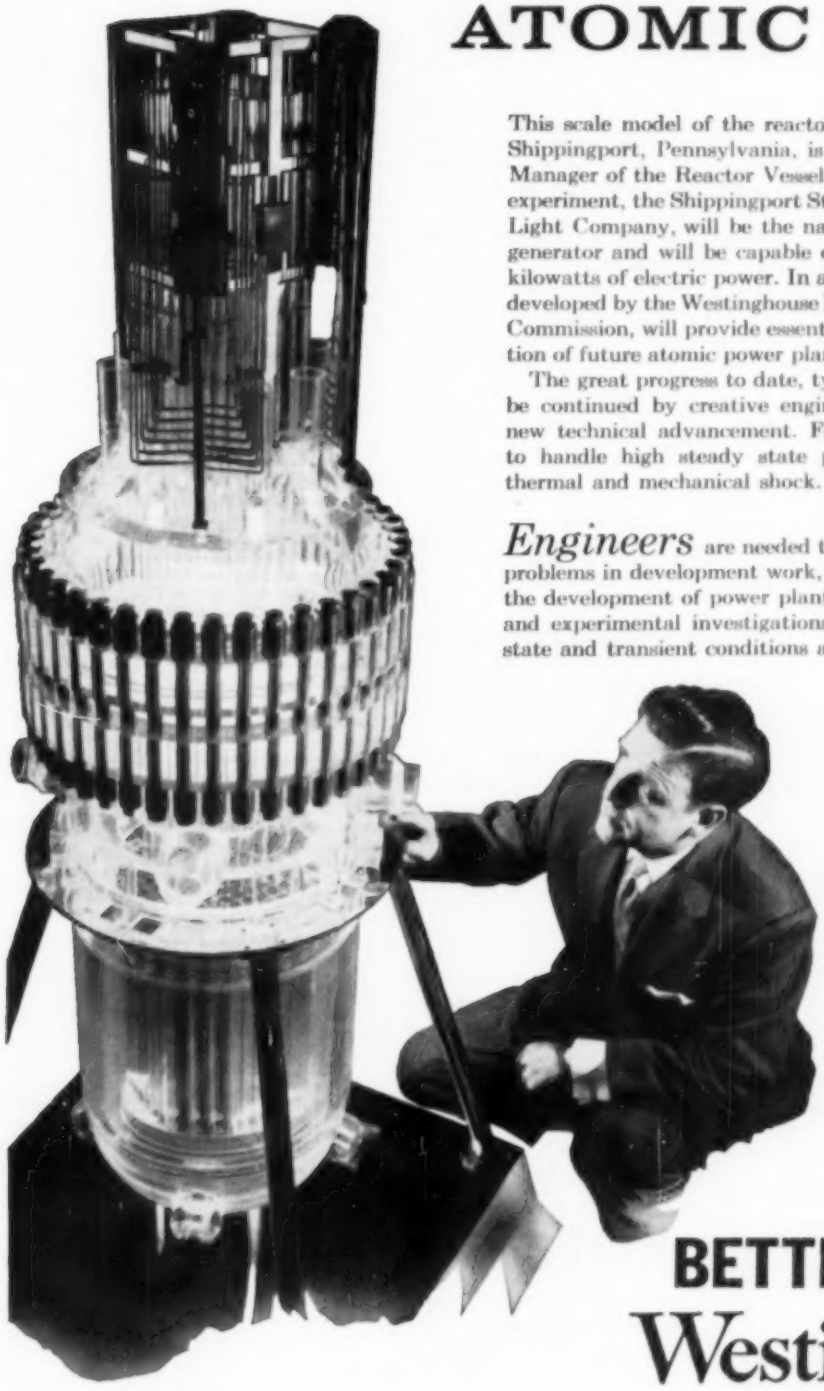

This scale model of the reactor for the atomic power station at Shippingport, Pennsylvania, is being checked by P. A. Halpine, Manager of the Reactor Vessel Design for this project. No small experiment, the Shippingport Station, to be operated by Duquesne Light Company, will be the nation's first full-scale atomic power generator and will be capable of producing a minimum of 60,000 kilowatts of electric power. In addition, this plant, which is being developed by the Westinghouse Bettis Plant for the Atomic Energy Commission, will provide essential data for the design and operation of future atomic power plants.

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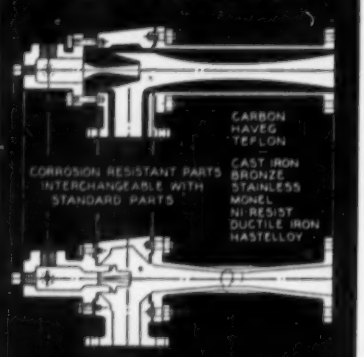

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the chemical engineer in MARKETING

(*Continued from page* 146)

Haveg Industries appoints **John B. Mackenzie, Jr.,** as assistant general sales manager.

Newly-appointed members of the petrochemical process sales department of Universal Oil Products Co. are **Raymond A. Erickson, Robert A. Moody,** and **William M. Swanson.**

Monsanto's Organic Chemicals Division announces several transfers of sales personnel. These changes include **J. Paul Ekberg, Jr.,** to Los Angeles as district sales manager; **Jack C. Hutchison** to St. Louis as manager of intermediate chemicals sales; and **Ernest S. Robson, Jr.,** to New York as assistant district sales manager. Changes are effective March 18, 1957.

Robert Potter becomes New England sales manager for the Alloy Tube Division of the Carpenter Steel Co., Union, N. J.

Necrology

William P. Burton, 39, research supervisor, M. W. Kellogg Co.

Richard M. Wick, 53, research engineer, Bethlehem Steel Co.

A. N. Parrett, 60, vice-president, Rayonier, Inc.

A. Clarence Dees, 43, Research & Development Department, Deep Rock Oil Corp.

David A. Berman, 20, senior in chemical engineering, University of Maryland.

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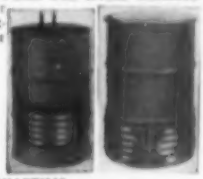

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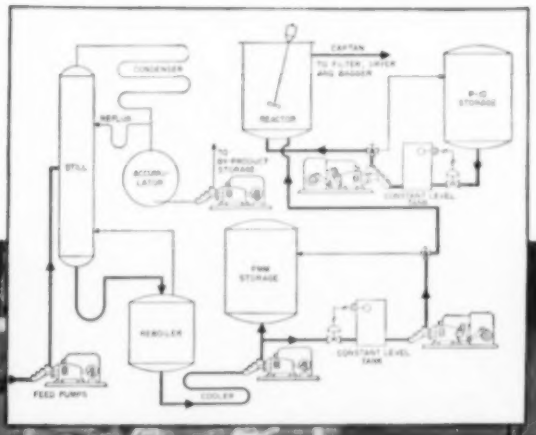
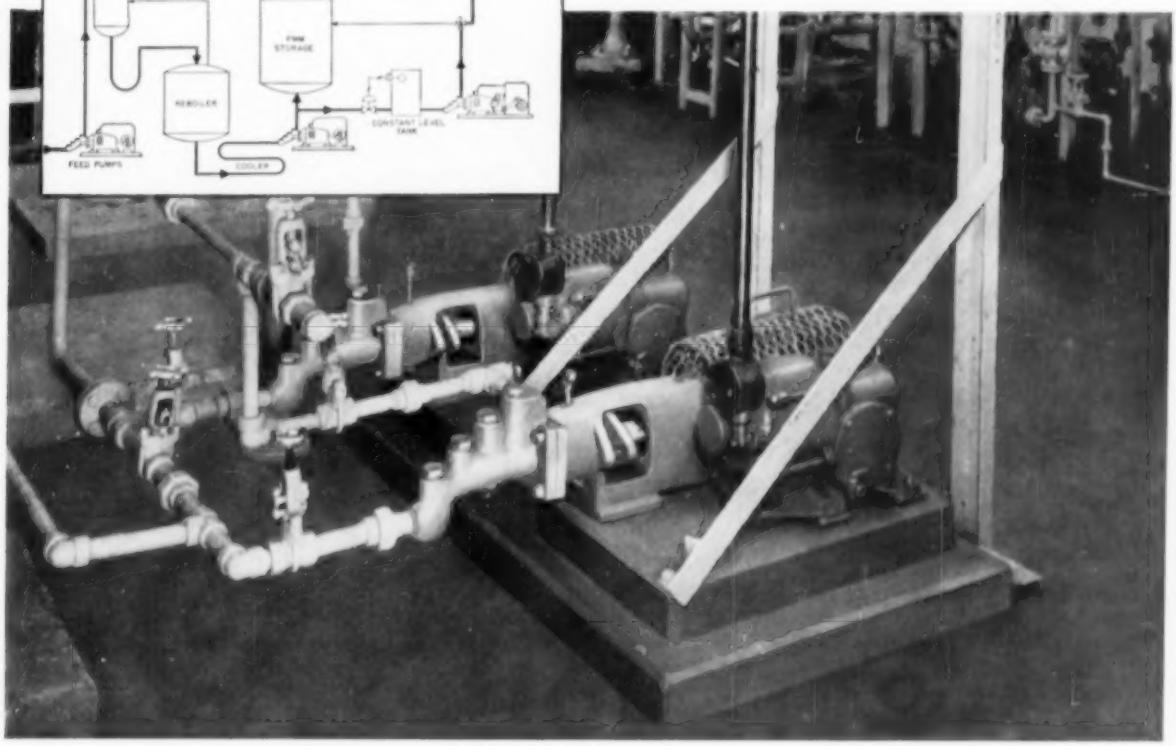
news and notes of A.I.Ch.E.

United Engineering Center is official now . . . It is the new name for the joint home of the engineering societies . . . The Real Estate Committee of the United Engineering Trustees is investigating sites in New York City owing to the excessive cost of remodeling the old Engineering Building, which in any case would not result in the kind of engineering home that will serve the best interests of all. . . . C. E. Davies, Secretary of the American Society of Mechanical Engineers, has been appointed by U.E.T. as coordinator of the new building . . . Davies will retire as A.S.M.E. Secretary at the end of 1957 but will continue to coordinate the requirements of the various societies in the new building after his retirement . . . The campaign for funds got underway early when Joe Lawrence & Tom Jackson, chairman & vice-chairman of the New York Section of A.I.Ch.E., presented President Barrett of U.E.T. & W. F. Thompson, Chairman of the U.E.T. Real Estate Committee, with a check for $500, a gift from the Local Section . . . This represented the first contribution to U.E.T. for the new building &, as Barrett and Thompson commented, about 20,000 such checks are going to be needed before the dream is fulfilled . . . There will be four different campaigns . . . a campaign to industry and foundations, a drive by each society to individual members, an appeal for gifts from individuals, & a special approach to New York City civic interests. . . . An extensive brochure describing the advantages of an engineering building to the engineers of the United States is now being prepared. **Career Guidance** by Local Sections is a growing activity . . . As an example of typical local section work in this area, the New Jersey Section of the A.I.Ch.E. has a Guidance Committee under the direction of Ralph Cohen of Hoffmann-LaRoche, & already some forty-four schools this year have had visiting speakers from the New Jersey Section of A.I.Ch.E. & other local engineering groups talking to the students on the advantages of an engineering career . . . This work is planned in conjunction with an E.C.P.D. committee & the willingness of local engineers to speak to students is advertised in a brochure sent to career counselors at the various high schools in New Jersey with full instructions on how such speakers may be obtained. . . . If any member knows of similar programs in other local areas, will he please drop a line to the Secretary's office. **Nominating Committee** chairman this year is Past President Walter Whitman of M.I.T. . . . For Local Sections and friends of possible candidates considering action by petition, here is this year's schedule . . . the Constitution requires that the nominating ballot be received no later than nine weeks prior to an Annual Meeting . . . a special Council By-law asks that the Nominating Committee bring in its selections at least 20 weeks before the Annual Meeting so that the candidates may be presented to the Members early via *C.E.P.* . . . it is hoped that candidates will be publicized in the August issue . . . earlier if possible . . . so the timetable is as follows . . . Nominating Committee selections to be finished by the week of July 14 . . . candidates to appear in the August issue of *C.E.P.* . . . the first week of October the latest possible date for candidates' names to be submitted by petition. Should any such petition be in the offing, the section members responsible are urged to try to get candidates' biographical data, picture, etc., into A.I.Ch.E. headquarters no later than July 15 to ensure publication in *C.E.P.* **Student Chapter Counselors:** University of Texas, R. S. Schechter . . . Villanova University, H. H. Yuen. **Admissions Policy** recently was reaffirmed by Council & ought to be spread here informally before the membership . . . Council has asked that the Admissions Committee consider as broad fields for the practice of chemical engineering (provided the applicant for membership in A.I.Ch.E. is using his chemical engineering training and its principles in these areas) . . . education, research, development, design, patent prosecution, economic appraisals, sales, contracting, construction, operation, maintenance, and management . . . Heretofore these had been considered on a more or less informal basis as chemical engineering fields by the Admissions Committee but now Council has made it official . . . Another important change is the reinterpretation of the qualifications needed by a man who has studied chemical engineering in an unrecognized school . . . Previously Member grade required that a graduate from such a school have ten years of experience and five years in responsible charge . . . This term has now been reduced by Council, at the suggestion of the Admissions Committee, so that a graduate with a degree in chemical engineering from a nonaccredited school may obtain Membership in A.I.Ch.E. with six years of experience and four years in responsible charge . . . This is the same as the requirements for graduates in chemistry and the other engineering fields.

F.J.V.A.



In the production of Captan, an agricultural fungicide, Milton Roy pumps control feed rates in the separation of perchloromethylmercaptan by distillation at Calhio Chemicals, Inc., Perry, Ohio. The accurate delivery of these pumps also permits reacting of chemicals in stoichiometric amounts.



Controlled Volume Pumps hold critical material balances

Provide precise control of distillation columns

You can step up the efficiency of complex distillation processes with Milton Roy Controlled Volume Pumps. These pumps make possible extremely close control of chemical feed rates and rates at which distillates are withdrawn from the still. With precise control of feed and distillate rates comes the fine balance of chemical materials which is essential to ultimate product quality.

Accurate in delivery within ± 1%, Milton Roy Controlled Volume Pumps serve equally well as flow controllers, ratio controllers, or final control elements. They're available in simplex, duplex, and multiple liquid end types. Capacities from 3 milliliters per hour to 45 gpm. Pressures to 50,000 psi.

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Write today for application data on Controlled Volume Pumps in Process Instrumentation (Bulletin 1253).

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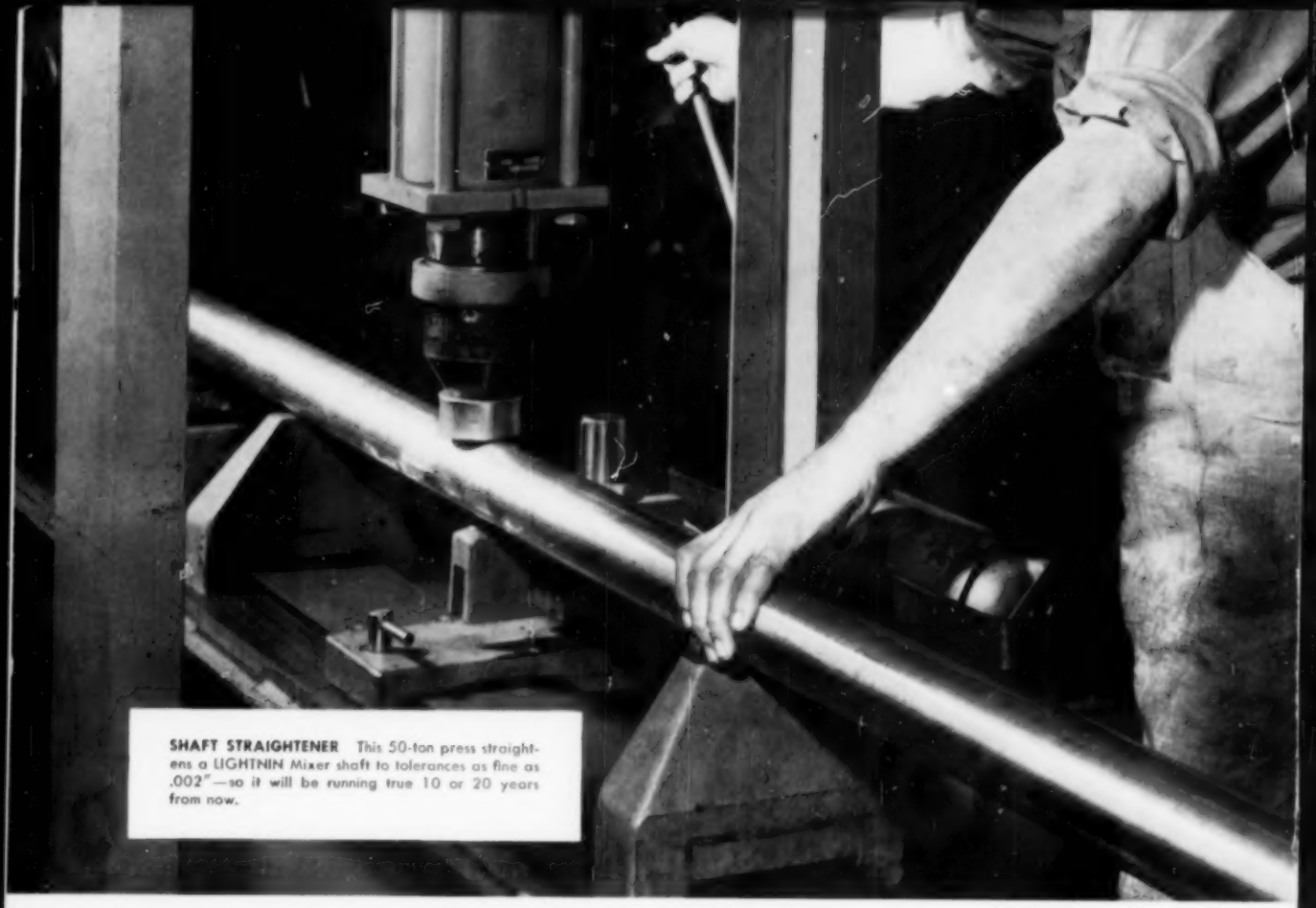
Engineering representatives in the United States, Canada, Mexico, Europe, Asia, South America and Africa



SHAFT STRAIGHTENER This 50-ton press straightens a LIGHTNIN Mixer shaft to tolerances as fine as .002"—so it will be running true 10 or 20 years from now.

How to prevent **shaft failure** *when you mix fluids mechanically*

An out-of-line shaft on a mechanical mixer can be bad for your process, in more ways than one.

A shaft that bends or breaks may not cost much to replace—but can cost plenty in downtime. Even a slight misalignment in the shaft can set up stresses leading to shaft breakdown. And an off-true shaft makes it impossible to operate a stuffing box or rotary mechanical seal efficiently.

Importance of straightness

That's why every LIGHTNIN Mixer shaft must pass the test shown above, so it will run true when it gets into your tank.

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For example, you can use two different metals in the same two-piece rigidly coupled shaft: corrosion-resistant alloy in the tank, plain steel above the splash line. This two-piece construction has many other advantages; it's possible only because of the most careful straightening and machining.

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You can draw on a wealth of cost-cutting shaft application data, too, when you mix with LIGHTNINS. What's the most economical shaft diameter that lets you skip the upkeep of a submerged steady bearing in the tank bottom? How can you avoid paying for excessive "safety factor" in an overhung shaft that must run smoothly during draw-off? We can give you the right answers, quickly and without guessing—based on thousands of test runs in a uniquely equipped fluid mixing laboratory.

This extra care in shaft design and application is just one example of a *way of thinking* that goes to work for you when you unload a fluid mixing problem on a specialist engineering firm like MIXCO.

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MIXCO fluid mixing specialists

SHAFT DEFLECTION TEST records the play of fluid forces on LIGHTNIN Mixer impeller and shaft. Data permit accurate prediction of shaft critical speeds, and most economical shaft selection for a given mixing job.

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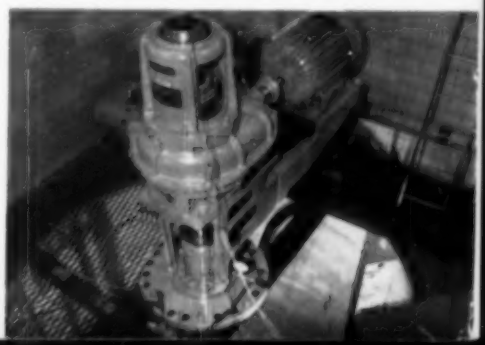
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